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[FOURTH SERIES.]

ART. XXVII.—*The Compressibility of Colloids, with Applications to the Jelly Theory of the Ether;* by C. BARUS.

1. COLLOIDS in view of their varied and frequently anomalous physical properties,* not to mention their tremendous biological importance, offer a fascinating field of research. I have, however, undertaken the present experiments rather with ulterior motives, because of their bearing on the elastic properties† of glass, geologically considered. Apart from this, certain practical difficulties have presented themselves in the course of my work for which I hope the present paper will suggest a remedy. Thus, in endeavoring to ascertain the effect of pressure on solution,‡ I was invariably confronted by the difficulty that the solute precipitated by pressure collects at the bottom of the piezometer tube, is segregated from the bulk of the solvent and therefore no longer in place for solution on removal of pressure. Methods which work faultlessly for fusion are thus apt to fail when applied to solution. Now if it can be shown that the physical properties of a solution vary but slightly in presence of a colloid, that the former may be made viscous enough to retain the precipitate in place during compression, I see no reason why the fusion methods are not adapted for the study of solutions.

A final inquiry of great interest is the compressibility of well coagulated colloids, seeing that compression is apt to be accompanied by the breakdown of stress in a solid medium. Indeed I here encountered some astonishing phenomena, and a

* On analogies in the thermal behavior of india rubber jelly, muscular tissue, etc., see Bjerken, Wied. Ann., xliii, p. 817, 1891.

† See my paper in this Journal, xli, p. 110, 1891.

‡ Bulletin U. S. Weather Bureau, No. 12, p. 18 et seq., 1895.

large part of the present paper will be devoted to them. I say astonishing, as I have been able to force little mercury projectiles, often less than $\frac{1}{10}^{mm}$ in diameter, though a solid wall of coagulated jelly over 15^{cm} thick, by the directed action of hydrostatic pressure applied on the outside of the wall. I know of no other case of well-defined persistent motion, performed by bodies in a highly viscous medium, and resulting from the breakdown of mechanical stress within it, wholly without the action of external forces "acting at a distance."

2. The earlier literature of the subject is meagre and I may refer regarding it to a paper by G. de Metz,* to whom some of the best data are due. He accentuates the variable character of the constants observed and certain changes (gelatine) in the lapse of time. Papers like those of Fraas,† Maurer,‡ and others quoted by the former, refer to the elastics and to the viscosity of colloids, in a way differing from that here considered.

I do not in the present paper aim at reaching more than an estimate as to how far the elastic properties of a solvent are modified, when it is made thoroughly viscous by the addition of a suitable quantity of colloid. I have therefore subjected the bodies to pressure in capillary tubes, a method which though it does not admit of the application of very high pressure, has the undeniable advantage of exhibiting the progress of the experiment to the eye throughout. I have already described the precaution necessary in a former paper§ in connection with an extensive survey of the compressibility of liquids, and need therefore only state here that the body to be examined is introduced into a well annealed capillary tube of fine bore between two terminal threads of mercury. One of these (the upper) is sealed in place; the lower is movable and transmits the applied pressure. The lower meniscus of the upper and the upper meniscus of the lower thread are observed by aid of a cathetometer, through a clear glass boiling tube, of the kind frequently described in my high temperature work.‖

3. It is sufficient for the present purposes to examine two classes of colloids, representing extremes of compressibility. In the first case of low compressibility water is to be the solvent and gelatine and albumen were selected. In the second case (high compressibility) ether is the preferable solvent and solutions of pure india rubber are thus available.

A solution of 10 per cent by weight of clear gelatine in water sets quite firmly at ordinary temperatures and is not too

* G. de Metz, Wied. Ann., xli, p. 663, 1890.
† Fraas, Wied. Ann., liii, p. 1074, 1894.
‡ Maurer, Wied. Ann., xxviii, p. 628, 1886.
§ This Journal, III, xxxix, p. 478, 1890.
‖ Cf. Bull. 54, p. 88, U. S. Geolog. Survey, 1889.

viscous at higher temperatures to admit of introduction into a fine capillary bore. Greater difficulty is experienced with the 20 per cent solution. Albumen is advantageously introduced in the natural state as white of egg.

Considerable trouble was encountered in charging the tube with india rubber, though a 5 per cent solution in ether was manageable. The presence of traces of sulphur is apt to foul the meniscus, while the absorption of water from air by condensation is unavoidable during filling.

The remarkable volume-elasticity of water makes it a difficult body to observe by the present method. Thus for a thread 10^{cm} long, the motion of the meniscus will scarcely exceed $\frac{1}{2}$ millimeter per 100 atmospheres. For longer threads and higher pressure the case is proportionately favorable, but in no practical case is an accuracy of more than 3 or 4 per cent to be looked for, quite aside from the compressibility of the glass. The latter is best eliminated and sufficiently so for the present comparisons, by examining all the samples as far as possible in the same tube. For ether the case is 2 to 8 times more favorable, depending on temperature.

4. The following data, selected from a large number of similar experiments, will best exhibit the results obtained. In the tables θ denotes the temperature of the thread of total length L in cm., while l is the decrement of length for the pressure p (in atmospheres) stated. Hence l/L, the decrement of length per centimeter, is also the decrement of volume at the given temperature and pressure. The solvent and colloidal solution may be conveniently compared in two ways: one is to plot l/L varying with p for each substance; the other to compute the mean compressibility β within the same pressure interval (usually about 200 atm.).

TABLE 1.—Compressibility of water and colloidal solutions of gelatine and albumen in water.

	Water.			Gelatine 10%.			Albumen (Natural).	
θ, L	p	l/L	θ, L	p	l/L	θ, L	p	l/L
23°	0	·0000	----	---	----	22°	0	·0000
17·4cm	83	037	---	---	----	12·3cm	81	039
	160	075	----	---	----		128	061
	226	108	----	---	----		191	093
100°	0	·0000	100°	0	·0000	----	---	----
18·1cm	83	046	21·1cm	116	058	----	---	----
	180	098	----	211	100	----	---	----
	244	133	----	282	133	----	---	----

Corresponding values of l/L and p are given for water, gelatine and albumen in aqueous solution in Table 1. At ordi-

nary temperatures water and albumen on graphic representation show nearly the same compressibility, so far as the present method goes; at 100° gelatine is throughout less compressible than water, the difference being as large as 10 per cent.

In Table 2 I have computed the compressibilities β for each of the three cases, at different temperatures θ. Observations were made in triplets, beginning and ending in the same low pressure at each temperature. This eliminates change of temperature due to cooling of the water bath. The colloids were kept liquid throughout; though the albumen turned white gradually at the higher temperatures, it did not at once set firmly.

TABLE 2.—Compressibility of water and of colloidal solutions of gelatine and albumen in water.

Water.			Gelatine 10%.			Albumen (Natural).		
θ, L	p	$\beta \times 10^6$	θ, L	p	$\beta \times 10^6$	θ, L	p	$\beta \times 10^6$
23·3°	5	..	21·4°	5	..	22°	5	..
17·4cm	160	48	20·3cm	177	51	12·3cm	128	50
100°	10	..	23·6°	5	..	28·8°	4	..
18·1cm	198	52	20·3cm	165	50	12·3cm	181	50
			25·8°	12	..	27·5°	4	..
			20·3cm	190	52	12·3cm	178	47
			29·2°	12	..	49·5°	4	..
			20·4cm	188	53	12·4cm	192	52
			32·0°	18	..	53·5°	4	..
			20·4cm	187	52	12·4cm	176	50
			36·8°	30	..	57°	1	..
			20·4cm	201	49	12·5cm	190	50
			43·5°	30	..	59·6°	1	..
			20·5cm	186	50	12·5cm	203	48
			53·3°	31	..	*63·6°	2	..
			20·6cm	181	52	12·5cm	187	55
			100°	10	..	*67·5°	11	..
			21·1cm	185	51	12·5cm	195	52
			100°	12	..			
			21·1cm	197	51			

The results are not unlike the preceding set. The compressibility throughout remains very nearly that of water.

* Coagulating but not set. Threads break off, observation difficult.

Neither for gelatine nor for albumen is an increase of compressibility with temperature certainly indicated, whereas this is definitely the case with water.

It is difficult to state whether these detailed results are real. I will pass it over, mentioning merely that it is always a delicate question to decide whether the heat generated on compression has all been dissipated. In a cooling water bath, moreover, the residual effects of thermal expansion are apt to be superposed as the compression results. Finally in case of coagulated albumen, threads break off and are lost in the opaque body.

The endeavor was now made to prepare as concentrated a solution as could be filled into the fine capillary bore. The ingredients were weighed out for a 20 per cent solution, though the concentration may have been less. It coagulated firmly, showing marked elasticity in threads.

Measurements were first made for the coagulated thread as will be shown below, § 7 et seq. After this the tube was kept at 100° for some hours and examined from time to time. The earlier results contain no additional information and will be omitted. The final data are given in Table 3. Compressibility β refers to the total interval from $p=0$ to the value of p given.

TABLE 3.—Compressibility of a 20 per cent solution of gelatine in water.

θ, L	l/L	p	$\beta \times 10^6$
100°	·0003	7	--
17·01^{cm}	056	114	49
	103	216	48
	156	319	49
	185	381	49
	126	268	47
	082	171	48
	038	87	44
	003	8	--

These new data practically coincide with the former albumen and gelatine (10 per cent) values; if anything the former show greater compressibility. They coincide nearly with the compressibility of water at 23°, and fall definitely below the water compressibility for 100°. Little or no effect is therefore observed by the additional concentration of the new solutions.

5. Table 4 contains results similar to Table 1 for ether and an etherial solution of caoutchouc (not vulcanized). If the volume increment l/L be laid off in terms of the corresponding pressure p, it is found that the curves for the colloidal solution and the solvent ether coincide very nearly both at low temperature and at high temperature. Since in the former

case the colloid is at a lower temperature (24°) as compared with ether (29°), this would indicate greater compressibility for the india rubber solution. Even at 100° this state of things is not quite wiped out. These results thus recall the case of the preceding paragraph.

Here again, however, I do not wish to insist on these detailed observations, because of manifold sources of error incident to the method. The present results demonstrate all that I asked of them in showing that to ascertain the effect of the colloid on the compressibility of the solvent, it is necessary to use some much more sensitive method than the direct capillary tube comparisons of the present paper.

TABLE 4.—Compressibility of ether and of an etherial solution of caoutchouc, about 5 per cent by weight.

Ether.			Caoutchouc-ether solution.		
θ, L	p	l/L	θ, L	p	l/L
29°	20	·0000	23·9°	45	·005
14·57^{cm}	100	137	7·72^{cm}	123	17
at 20^{atm}	200	291	at 20^{atm}	195	27
	300	423		286	38
	400	540		---	---
100°	10	·0000	100°	57	·021
16·85^{cm}	100	·0357	8·93^{cm}	148	51
at 10^{atm}	200	·0653	at 10^{atm}	221	71
	300	·0876		298	88
	400	·1060		---	---

6. The last two paragraphs, therefore, show in a general way that the compressibility of a colloid is essentially determined by the solvent for a wide range of concentration and throughout enormous variations of viscosity, so long as the solution is liquid, however viscous it may be. In so far as compressibility is decreased, the decrement will not exceed the amount corresponding to the displacement produced by the mere bulk of colloid present.

The essential identity of behavior of a solvent in the presence or absence of dissolved colloid seems first to have been definitely expressed in 1888 by von Tiezen-Hennig,* reasoning from the results of electrolytic experiments.

In this place I may add a correlative result obtained in my experiments on the solution of vulcanized india rubber,† where it is shown that the melting point of the coagulated colloid is practically independent of the solvent contained.

* "Ueber scheinbar feste Electrolyte," quoted by Bjerkén, l. c.
† This Journal, III, xlii, p. 359, 1891.

7. As has been stated, these inferences refer specifically to liquid colloidal solutions. The interesting question now presents itself: In what respect does compressibility change when the liquid colloid thoroughly coagulates,* or changes in relation to viscosity from a viscous liquid to a soft solid.

The results for coagulated gelatine solutions are given in Table 5; but the datum β is here, at the lower temperature, merely a superior limit compressibility, for reasons which I shall presently explain. § 8. The true compressibility is probably less than $\frac{1}{8}\beta$; indeed no true compressibility may have been measured. As temperature rises (33°, 41°, 51°), approaching the melting point, the normal compressibility† of the solvent water is rapidly approached here, as was the case in Table 2 for albumen. Stress therefore breaks down the friable solid, triturates it as it were, the colloid being altogether too soft to resist the advancing column of mercury appreciably like a solid. Whenever a sufficient number of internal discontinuities is at hand (unstable configurations, virtually) the solid is proportionately liquid.

TABLE 5.—Coagulated colloids.

Gelatine 10 per cent.				Albumen* coagulated at 100°.	
θ, L	p	l/L	$\beta \times 10^6$	θ, L	
22°	0	.000	—	22°	No motion of meniscus observed as far as 200 atm. At higher pressures threads of mercury pierce the core and make further measurement impossible.
20·2 cm	97	1	10	12·7 cm	
	210	2	10		
	0	0	—		
Another sample:					
24°	0	·0000	—		
13·2 cm	105	23	26		
32·7°	0	·0000	—		
13·3 cm	104	49	47		
40·8°	0	·0000	—		
13·3 cm	92	38	41		
51°	0	·0000	—		
13·4 cm	117	55	47		

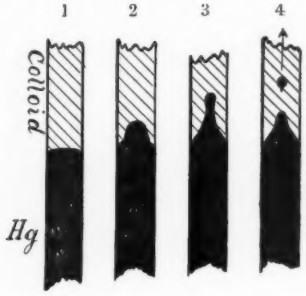
*Heated about 10 minutes, the white thread expands. Examined next day after setting. Meniscus fouled by sulphur corrosion.

8. The compression of the solid colloid is accompanied by characteristic phenomena (as has just been intimated), deserving special examination. They are shown in the annexed figures, where the contiguous threads of mercury (below) and colloid (above) meeting at the lower meniscus are alone represented, the walls of the capillary tube containing the threads being ignored.

* That time for setting is essential here has already been emphasized by de Metz, Fraas and others (l. c.), and in the above work with albumen.

† Cf. § 11, relative to suggestions of Carus-Wilson.

When pressure continually increases (very gradually), the meniscus in 1 passes into the conoidal form 2, thence into the unstable figure 3, from which presently a drop is shot off, upward. This exceedingly minute projectile may penetrate the whole column of coagulated colloid, 13^{cm} or even 20^{cm} long. The phenomenon repeats itself at consecutive intervals even at constant pressures.



FIGS. 1, 2, 3, 4. Deformations observed on compression of a coagulated colloidal thread, by a mercury meniscus advancing from below.

With the 10 per cent gelatine coagulum, on one occasion, I counted twelve of these little projectiles (on another thirteen, etc.), each less than $\frac{1}{15}$ mm. in diameter and disposed at regular intervals, i. e. nearly equidistant in the axis of the column of coagulated (solid) colloid. The top one rose 12^{cm} through the medium and against gravity, the lowest about 1^{cm} above the meniscus. On removing pressure five of them gradually dropped back upon the meniscus, which in the telescope soon resembled a bunch of silver grapes. When the tube is allowed to stand vertically over night with pressure removed, all drops often fall out of the colloidal column before morning. This motion of droplets, up or down, is equally evident to the naked eye.

At other times and particularly with older or abused columns, balloon-shaped projectiles even ·5^{mm} high break off and walk up leisurely through the colloid, say at a rate of 2$^{cm/sec}$. The motion on close inspection is apt to be jerky. In such cases, a trail of exceedingly small droplets, scarcely ·02^{mm} in diameter, is apt to be seen in the axis of the tube, where there was no such trail before, or even in advance of the large drop.

The phenomenon is best seen after slow cooling of the thread. On change of pressure slow creeping of drops across the crosshairs of the telescope is a frequent occurrence. Irregular dispositions of the drops were also often observed.

To further elucidate these phenomena additional experi-

ments were made with the 20% gelatine solution, after thorough coagulation. In two experiments I was fortunate in breaking off very short mercury threads while the colloid was still liquid, to indicate the nature of the strain above the meniscus. In one case this drop, originally ellipsoidal in form, sharpened upward as pressure increased, until at about 150 atm. the conoid completely *exploded*, giving rise to about fifteen small projectiles distributed along the lower 10^{cm} of the column of coagulated colloid. The motion, which is extremely swift at first, of the order of several meters per second, as I judge, dies down gradually within 5 to 10 minutes to the merest creeping.

A full protocol of a similar experiment on a continuous column, thoroughly coagulated after slow cooling from 100°, is given in Table 6. A drop of mercury originally nearly round in appearance was here also present just above the meniscus. As pressure increased, accompanied by the sharpening apex of the conoidal meniscus already described, the base of the drop in all cases remained apparently convex, while its sides sloped even more steeply than the meniscus of the column of mercury. It may have been reëntrant and the cone hollow, but I did not notice this.

TABLE 6.—Compression of a coagulated 20 per cent gelatine solution.

θ °C	L cm	p atm	Remarks.
24°	16·325	16	*
	16·310	92	(1)
	----	115	(2)
	16·310	130	(3)
	16·305	160	(4)
	----	170	(5)
	16·310	200	(6)
	16·300	265	(7)
	----	300	(8) Tube breaks.

* The tube originally showed a good meniscus (obtained by slow cooling from 100°) and a detached, apparently round *drop* of mercury a few millimeters above it.

(1) Both meniscus and drop sharpen conoidally, with the apices directed upward.

(2) Further sharpening. The drop shoots off one little projectile, tadpole-shaped, $\cdot 015^{cm}$ long, which penetrates upward *alone*, very fast at first, slowing up gradually to zero. The motion continues visibly several minutes. Another projectile follows in the same way. Both eventually stop about 4^{cm} above the meniscus and $\cdot 5^{cm}$ apart.

(3) Two more projectiles shot off consecutively from the drop. The two former rise but slightly; the latter come to rest below them.

(4) The top (original) projectile now rises, tadpole fashion, to 8^{cm} above the meniscus. The others gradually meet and coalesce, rise without meeting the first. Meantime new projectiles have been shot off by the drop, which successively rise, forming a close group 4^{cm} high. Simultaneously the very sharp meniscus of the lower mercury column has been firing projectiles through the

9. At first sight these phenomena seem to be of a capillary nature. Drops of oil break off in Plateau's well known experiments more slowly but otherwise in much the same way. The tendency to jerky motion and much else suggests the action of surface tension.

A moment's reflection shows, however, that surface tension cannot be the primary motive force,* since droplets of mercury often less than ·01^{cm} in diameter are to be projected through a coagulated (solid) colloid, a distance of 10^{cm} or more. Again these projectiles often start afresh in their motion (cf. Table 6), when many centimeters above the meniscus. In these fine bore tubes (diameter ·031^{cm}) capillarity necessarily plays an important part; but it is of entirely subordinate interest and I shall not further mention it.

The real phenomena is elastic in character. The original meniscus in figure 1 loaded with a uniform pressure upward from below, is deformed in accordance with a shear symmetrically around the axis of the tube. The colloidal meniscus yields very much as any elastic disc secured at the edges and uniformly loaded would do. It is strongest at the edges, which are sustained by the glass walls of the capillary throughout the length of the colloidal column, and weakest at its axial points. As pressure increases the strain gradually reaches the limit of

narrow dissepiment of colloid *into the drop*, replenishing it in substance but giving it the appearance of a grape cluster with apex upward.

(5) Further projectiles shoot off from the drop. They induce the 4^{cm} group to penetrate farther upward. The top group is stationary.

(6) Meniscus shooting into the drop at its base: the drop discharging many projectiles from its apex. They induce motion in the preceding group (without reaching them), which in their turn actuate the earlier group until finally the upper (original) group moves nearly to the top of the column. Various projectiles have coalesced. Distribution of projectiles from the meniscus upward is now as follows:

Meniscus	·00^{cm}	Projectile	5·73^{cm}	Projectile	13·41^{cm}
"Drop," clustered	·21	"	6 93	"	14·38
Projectile	·38	"	7·91	"	14·56
"	·51	"	8·13	Original Projectile	14·62
"	3·29	"	8·52		
"	3.33	"	10·13	Top meniscus	16·13
"	3·73	"	11·32		
"	3 90	"	12·40		

(7) Further projectiles shot off from drop, which is now smaller but *still in place.* Top projectiles stationary.

(8) After the tube breaks retrograde motion of the projectiles is observed, often covering 4^{cm}. The experiment has been spoiled by the accident, however, release of pressure being too sudden. Next day the projectiles are found to have aggregated in clusters of 2–6, irregularly along the unbroken column. Some have reached the meniscus. The drop is gone.

*The relevant formulæ are given in my paper in this Journal, III, xxxvii, p. 339, 1889.

rupture (fig. 3), until finally (fig. 4) the elastic resistance breaks down and axial rupture is the result.

To account for the motion of the projectile in fig. 4, it is to be remembered that the colloid is *solid* however soft it may be, and that therefore, in fig. 1, pressure is not transmitted upward appreciably more than a few centimeters above the meniscus. The surfaces of like stress are conoids symmetrically around the axis and with their apices in it; but these conoids rapidly become more shallow and flatten out horizontally from the meniscus upward. In fig. 4, however, the central parts of the colloid between the projectile and the apex of the meniscus is in a *discontinuous or quasi-triturated state;* i. e. solidity has here broken down with the advance of the projectile, temporarily at least, even though the whole of this part of the colloidal column is under pressure. The projectile has, as it were, ploughed out a channel.

Through this discontinuous or quasi-triturated canal pressure is transmitted as through a fluid. Hence the projectile is urged upward by hydrostatic pressure applied against its lower hemisphere and transmitted through the channel in question. The upper hemisphere of the projectile is pushed in this way continually against the unbroken coagulated colloid, whose elastic resistance is as yet too weak to resist the motion.

But the discontinuous or triturated colloid behind the projectile gradually seals itself up under pressure, which is therefore transmitted less and less fully. The elastic resistances in front thus gradually increase in relative effectiveness until rupture is no longer possible. The strain ceases to break down, the projectile stops.

10. One of the chief characteristics of the phenomenon is its repetition a dozen or more times, with gradually decreasing intensity, even at approximately constant pressure. This is less directly explained since the properties of the essentially compressible coagulate with respect to viscosity and rigidity are here brought into play, with the addition of a property to re-cohere or re-cement under pressure.

Pressure is brought up to the meniscus through mercury transmission instantaneously. It is transmitted through the coagulated colloid only to relatively short distances into the column above the meniscus. When this is ruptured, pressure is at once transmitted upward through the triturated channel, but the intensity of pressure experienced at any axial point of the colloid will be less as the point lies higher; for it is inconceivable that pressure can be transmitted through the extremely narrow channel of viscous body instantaneously. Thus a wave or a single swell of pressure gradually moves upward. Now if the colloid near the meniscus under full pressure has the

property of re-cementing into complete coherence, a gradually more marked relief of pressure will occur above the meniscus: for this pressure is slowly dissipating itself* throughout the whole upper column, access to which is shut off below. Hence in the lapse of time the original conditions will occur; there will be fresh rupture at the meniscus and a new projectile until the whole column has in this intermittent manner been subjected to constant hydrostatic pressure at the meniscus.

Briefly, pressure is transmitted upward as an advancing wave whose amplitude diminishes with the distance above the meniscus. This is followed by gradual subsidence of pressure throughout the column, and anon by a new pressure wave of like rapid motion upward and diminishing amplitude, but of less intensity; and so on.

5.

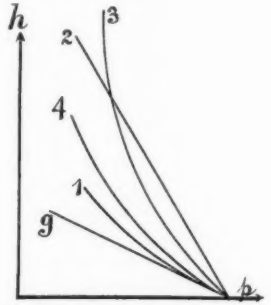


FIG. 5. Distribution of pressure, p, axially along the height, h, above the meniscus.

The annexed diagram, fig. 5, will make my meaning clearer. Let the height of the *axial* point be laid off vertically and pressure horizontally. Let g be the pressure-gradient for which rupture ensues at the meniscus (ordinate zero), pressure being here constant. Then the curve 1 may represent the distribution of pressure in the solid colloid at the instant of rupture; 2, the distribution immediately after rupture; 3, the distribution at a much longer time after rupture, when the upper part of the tube has partially accommodated itself to the new conditions, pressure increasing at the top of the colloidal column and decreasing gradually near the meniscus. Finally, in the lapse of time, 4 represents a pressure distribution having the same initial gradient g and conditioning fresh rupture.

*The volume decrement of a relatively small volume becomes the reduced volume decrement of a relatively large volume.

The scheme is to be repeated on a smaller relative scale for succeeding ruptures, and to be inverted for relief of pressure.

11. Looking at these facts as a whole, I conclude that no true compressibility (implying pure hydrostatic stress) has been measured for the coagulated colloid. The results are merely an evidence of compressibility and what is observed is a shear made possible by this compressibility. Hence the change from the very viscous fluid colloid to the coagulated (solid) colloid, looked at from the point of view of viscosity, is also a profound change in relation to compressibility. It is a change from compressibility to incompressibility relatively speaking, a change from the properties of the solvent liquid to those of the colloidal solute, supposing the body to be taken a little distant in temperature, either side of the melting point. Continuous colloid with liquid inclusions may therefore be inferred for the coagulated state, whereas in the liquid state the colloid is discontinuous.

Carus-Wilson* has ingenuously interpreted the stress-strain diagram of a metal particularly with reference to the yield points which terminate in permanent set, by the aid of Andrews' vapor-pressure diagram. The large abrupt yields of low temperatures gradually vanish as temperature rises and the metal becomes more plastic. Some such comparison might be instituted here.

12. What has impressed me as specially interesting in these experiments with coagulated colloids is their possible bearing on the dynamic manifestations of the ether. Following the lead of well known great thinkers, the hypothesis which attributes to the ether a jelly-like constitution, dynamically speaking, is familiarly in vogue to-day.

The phenomenon of the electric spark and the above experiments on the breakdown of mechanical strain as evidenced by the motion of the mercury projectiles are closely analogous. In both cases, there is an originally continuous and, I will say bluntly, a solid medium. When breakdown occurs there is in each case motion into the continuous strained medium, through the channel of broken down, discontinuous or triturated medium left in the wake. Finally there is recementation resulting in a new continuous medium.

Now the point I wish to accentuate is this, that we may distinguish between the same solid jelly-like medium in the continuous and in the discontinuous or triturated state, in the sense pointed out above; that the former transmits stress like a solid locally, showing rigidity, whereas the latter transmits it like a liquid, and in proportion as the degree of discontinuity is greater, virtually imparts hydrostatic stress. *The same ether*

*C. A. Carus-Wilson, Phil. Mag. (5), xxix, p. 200, 1890.

may therefore act, as the case may be, either as a liquid or a solid, just as, in the above experiments with gelatine, one and the same originally continuous and homogeneous body manifests itself in both roles, under the same conditions.

If this be admitted, I think that one may form at least a conception of a mechanism by which many ordinary dynamical phenomena may be looked upon as ether manifestations; and elsewhere I may endeavor to give a few tentative examples among many which I have entertained.

If in rigid dynamics, a body or a molecule can only move by breaking down the solid ether in front of it and leaving triturated ether in its wake, force* is needed to start it or in any way to change its state of motion. On the other hand, the body if sustained in place would resist such breakdown. Stress sufficient to break down the solid ether along given lines of force need not do so when the obstacle of a fixed body intervenes. In general, I hold the association of motion with the actual flux of a stress conveying fluid after the manner set forth in the present paper, not an unhappy conception, at least from the point of view of the law of the conservation of energy.

Brown University. Providence, R. I.

*During motion, stress in the continuous ether in front, and pressure in the discontinuous ether behind the body or molecule, may in the first instance be supposed to be in equilibrium. Note that fixity is an essential property of such an ether.

ART. XXVIII.—*Eolian Origin of Loess;* by CHAS. R. KEYES.

THAT the formation of loess deposits has ever been aided, to any appreciable extent, by the wind, has never, in this country, gained much credence. Almost without exception the aqueous hypothesis has been accepted in explanation of the deposits in the Mississippi Valley, in spite of the many grave difficulties presented in its general application.

Of late years, some American glacialogists have begun to suspect that possibly more than one agency has been involved in the production of the loess; that water is the principal agency in some cases, and in others the wind; while in some deposits both are concerned, or both kinds exist side by side.

The accompanying notes are presented on account of their direct bearing upon the eolian side of the question. They are confined to the deposits of the Mississippi Valley. The loess bordering the Iowan and other ice sheets is not considered—only those deposits that cover the bluffs of the great rivers of the region. Hence, for convenience, they are called by the long-used name Bluff deposits.

The prime reason for excluding from the present discussion the loess of the former ice fronts, is that it doubtless had a very intimate connection with the glacial agencies. Another reason is that the observations herein recorded were made largely upon the Bluff deposits alone. From this it might be inferred that an attempt is made to differentiate two great deposits of loess—one water-laid and the other wind-driven. Such is not the case. No means of discriminating between the two kinds of loess are yet known to be formulated. Should, however, the suggestion offered for the formation of the Bluffs loess be the correct one, the presence from bottom to top in the one, and the absence or existence only near the top, in the other, of limonite tubules, and an unusually prominent jointed structure may possibly prove to be reliable criteria. The nature of the fossils should also furnish a key to discrimination.

The areal distribution of the Bluff loess is peculiar. Prof. Chamberlin has recently* stated it as follows:

"The loess is distributed along the leading valleys. These embrace not only the great valleys, the Missouri and the Mississippi, but some of the subordinate valleys, as the Illinois, the Wabash and others. The loess is found along the Missouri River from southern Dakota to its mouth; along the Missis-

* Journal of Geology, vol. v, p. 795, 1897.

sippi River from Minnesota to southern Mississippi; along the Illinois and the Wabash from the points of their emergence from the territory of the later glacial sheets to their mouths. Along these valleys the loess is thickest, coarsest and most typical in the bluffs bordering the rivers, and grades away into thinness, fineness and non-typical nature as the distance from the rivers increases. In some instances the loess mantle rises to the divide and connects with the similar deposit of an adjacent valley, but the law of progressive fineness and thinness still holds. This relationship is such as to create a very strong conviction that the deposit of the loess was in some vital way connected with the great streams of the region."

The Bluff loess is not to be confounded with other similar fine silts that are found mingled with the glacial drift occurring in many localities and that are, by some writers, called loess. Along the Missouri River the Bluff loess forms a belt fifteen to twenty miles wide. From the mouth of this river to the Iowa line at least, the deposits appear to be much heavier and the belt much wider on the left bank than on the right side of the stream. The same seems true of the Mississippi River, at least south of St. Louis. The characteristic great thickness and coarseness at the river's edge, and, away from the stream to the margin of the belt, the gradual change of the deposit to greater fineness and less depth is everywhere apparent.

Missouri's great river, in its course across the State, passes from the drift-covered region to the driftless, and crosses and recrosses from one area to the other. The belt of Bluff loess lies sometimes on driftless areas, sometimes on what appear to be older silts, and then on drift and sands having a glacial origin. It appears to occupy the tops of the bluffs irrespective of underlying formations.

The Missouri River has long been known to be a stream that is heavily ladened with silt. Vast bars exist along its course, often a mile or more wide, and continuous on one side or the other the whole length from Dakota to its mouth. These bars are bare for a period of two or three months in the spring. During this time and immediately after the June floods they constitute boundless mud-flats which soon dry.

During certain periods of the year, marked by high winds, great "dust storms" prevail on the Missouri and middle Mississippi rivers. Down or across the valley sweep the strong currents of air, catching up the light silt particles from the river bars, whirling them about, and rolling them in dense yellow clouds up and out of the valley, and over the high bluffs into the open country beyond. The heavy dust-clouds rise high into the air. A score or more miles away from the stream, the latter's course is marked by the dark pall that hangs over it.

To the inhabitants of the region these dust-clouds often become almost unbearable. Dust is everywhere. It sifts through the closed windows and doors of the houses, covering everything within. Out-doors all is yellow with an impalpably fine powder. Man and beast suffer while the storm lasts.

The north and east side of the river suffers more and oftener than the south and west side. This is on account of the prevailing winds coming from the southwest in the spring and summer, when the silt bars are bare and dry. The north and northwest winds are most frequent during the winter when the ground is frozen or covered with snow.

The length of the "dust storm" varies. It may last only a single day, or it may continue through three or four days. The total number of days out of the year during which the dust clouds are driven with greater or less severity, is about thirty. During five-sixths of this period, the wind blows from the south and west.

The observations here recorded were made chiefly at Jefferson City during the years 1895–7. The measurements were made at the State capitol, which is located on the very brink of a high cliff, rising from the river's edge. The dust clouds thus came directly off of the flood-plain below. Numerous other notes were taken, but no accurate measurements made, at other places along the Missouri, as at Omaha, St. Joseph, Leavenworth, and Kansas City, and at St. Louis and elsewhere on the Mississippi.

The amount of dust brought up out of the valley at the Missouri capital and deposited on the top of the bluff was, in the several instances particularly noted, about one one-hundredth inch in a day. An open book placed in a protected nook was after a few hours so covered with dust that the print could not be distinguished. For the period of 25 days this would indicate a deposit of about one-quarter inch in a year, which is probably not far from an average for the margin nearest the river on the north side; while on the south side of the stream the total annual deposition would be very much less.

The amount deposited each day at any one place depends to a large extent upon the relation of the direction of the wind and that of the stream valley, very much less silt dust being carried out when the direction of the wind is directly across the valley than when the two directions are at an angle. In the latter case when the bare silt areas are exposed to the full sweep of a strong breeze, the dust rises high in the air and is carried far inland. The observations already noted were made chiefly at the point where there was a direct sweep of about ten miles. The daily amount carried would be, therefore,

somewhat in excess of what it would be for the whole stream. One-tenth instead of one-fourth of an inch might be perhaps more nearly correct for the mean yearly deposition. St. Joseph, Kansas City, Glasgow and St. Charles should have unusually heavy deposits of loess.

There is another factor to be taken into consideration in estimating loess deposition. Loess is not governed by the ordinary laws of erosion. While the deposits are subject to degradation and the action of running water, neither of these agencies is as destructive as in the case of most other soft materials. Loess is porous, and absorbs as a sponge most of the rain-waters falling upon it. Only the severest freshets erode it appreciably. Its capacity for resisting weathering and erosion are well shown by the perpendicular sides of road cuttings made in it, where the marks of the pick and shovel remain visible for several years.

Loess districts appear to be areas of exceptional fertility. Plant life flourishes luxuriantly even when in adjoining tracts not covered by the deposit only a scant vegetation is supported. The peculiar porosity of the loess gathers in the maximum amount of water, holds it, and gives it out again gradually, during the dry season. The belt is one of unusual dampness and there is within its limits always an abundance of moisture for plant life.

The plant roots penetrate the loess to great depths, and this is perhaps the main cause of the marked vertical cleavage developed in many of the deposits. The roots, instead of spreading out a few inches beneath the surface as in most soils, in loess appear to penetrate straight downward much farther than is usually the case. In decaying, the exterior corky layer of the rootlets lasts much longer than the other parts. As the interior disappears the outer tube finally collapses, leaving a flat band or ribbon-like film that long resists further decay and finally only the insoluble mineral particles. If it can be shown that the cleavage is eminent from bottom to top of some deposits and only at the top of others, a criterion might be established for distinguishing between wind and water deposits.

The dense vegetable growth well protects the loess from the destructive effects of wind and water. When once deposited the silt particles are only with great difficulty disturbed. Silt dust blown up from the valley strikes the thick vegetation and is acted upon in the same way that it is in water when the current is checked. The particles come to rest around the roots and gradually build up the ground. Each year's vegetation is on a little higher level than the last.

A characteristic feature of some loess deposits is the small, cylindrical, concretionary masses that are commonly called loess

tubules. They are sometimes lime; sometimes iron. The origin of the latter appears to have been overlooked. As the plant roots begin to decay they accumulate around them crystalline coatings of iron pyrites, which finally form little pipes one-eighth to one-fourth of an inch or more in diameter, and several inches long. The pyrites soon changes to limonite. Along the Missouri River, all stages of tubule formation are readily made out—from the decaying rootlet, with a thin film of pyrites on it, though the crystalline aggregate of pyrites, to the pyrite-limonite cylinder. Around all of the roots pyrites does not form. Whether or not the pyrites is deposited on the roots of a particular plant is not known. The fact that the tubules are very abundant in certain spots and sparingly distributed or absent altogether in others suggests that the nature of the plant has something to do with their occurrence.

As a possible means of discrimination between water-laid and wind-formed loess the tubules may prove an important criterion. Should they occur at all levels in a deposit, the indication would be that it had accumulated among plant growths; whereas if they are found only at the top, it would be suggested that the vegetation did not cover successively every layer of loess, but only, as at present, the upper part.

The chemical process of the accumulation of the iron pyrites around the decayed roots of the plants in the loess is doubtless analogous to the formation of the principal sulphide ores of lead, zinc and iron in the same region of south Missouri. It is a comparatively rapid process under favorable circumstances, different rates of deposition prevailing with the different ores. A decade or even less is probably ample time for the accumulation of iron pyrites to a thickness of a quarter of an inch. The process is in all likelihood in operation at the present time and the deposition of pyrites in tubules, as well as the zinc and lead in the rock crevices, is going on to-day as rapidly as it has ever gone on in the past.

The fossils of the loess have never received the critical attention that they deserve. A careful consideration of them promises very fruitful results. Their real significance and possible usefulness as a means of discriminating between loess deposits having different origins can only be merely alluded to here. In proportion to the great amount of study that the loess has received from many individuals, it is a rather remarkable fact that the fossils have received so little notice. What little special consideration they have had is contradictory, and is from a biological rather than from a geological standpoint. R. E. Call and B. Shemik have both collected largely the loess fossils; but the conclusions reached are diametrically opposed. The one argues that the organic remains when compared with

the same species now living in the same region presented a marked depauperation, attesting a much more rigorous climate in glacial times than at present. The other writer, after examining a much greater amount of material, from a very much larger area, shows that the loess fossils are not only not smaller in size, but if anything slightly larger than existing individuals.

Some fifty species of animal remains are credited to the loess formations of the upper Mississippi Valley. Among these are several vertebrates. Whether or not the latter really belong to the loess or are to be regarded as having been incorporated by slipping and over wash of the deposit, is not known.

Mollusean shells form the great bulk of the loess fossils. With the possible exception of half a dozen isolated exceptions none of the species are bivalves. The large majority are land forms, with a few water species that do, however, inhabit small temporary pools. In the Bluff loess more than nine-tenths of the total number of individuals belong to species that are found only in unusually damp situations. They are those species that to-day occur most abundantly in the loess areas. The species having an optimum habitat that is not excessively moist have not been observed to occur abundantly in the Bluff loess, though they flourish in the country bordering the loess belts. These loess fossils are apparently those forms that have lived among the plants of the belt. On the death of the animals the shells simply dropped down on the ground beneath and were covered.

On the other hand, there occur in the loess of the ice fronts shells of mollusks that do not now live in the region. Such are *Helicina occulta* Say, *Patula strigosa* Gould, the boreal species of Pupa, and other northern forms. The loess fossils should be studied with reference to their possible use as a means of discriminating between loess deposits having different origins.

The presence of vertical root remains and limonite tubules, from the bottom to the top of the Bluff loess, the luxuriousness of vegetation covering the loess belts, the "dust" storms on the larger silt-ladened streams, the peculiar relations existing between the prevailing winds and the distribution of the loess deposits, all point to fruitful sources of inquiry regarding one of the most obstinate problems in Pleistocene geology. A possible means is suggested of discriminating between deposits lithologically similar, that are doubtless formed by very different agencies and under very different conditions. The inference to be drawn is that the eolic processes have been at work upon certain deposits in the Mississippi Valley in a manner and to an extent that has been, heretofore, little appreciated.

ART. XXIX.—*On Dikes of Felsophyre and Basalt in Paleozoic Rocks in Central Appalachian Virginia;** by N. H. DARTON, U. S. Geological Survey. With notes on the Petrography by ARTHUR KEITH, U. S. Geological Survey.

THE occurrence of igneous rocks in the central and northern Appalachians is very unusual, for the detailed work in various portions of the province from Alabama to New York has only resulted in the discovery of a dike in central Pennsylvania and the small group of dikes west of Staunton, Virginia, which I described in 1890.†

1.

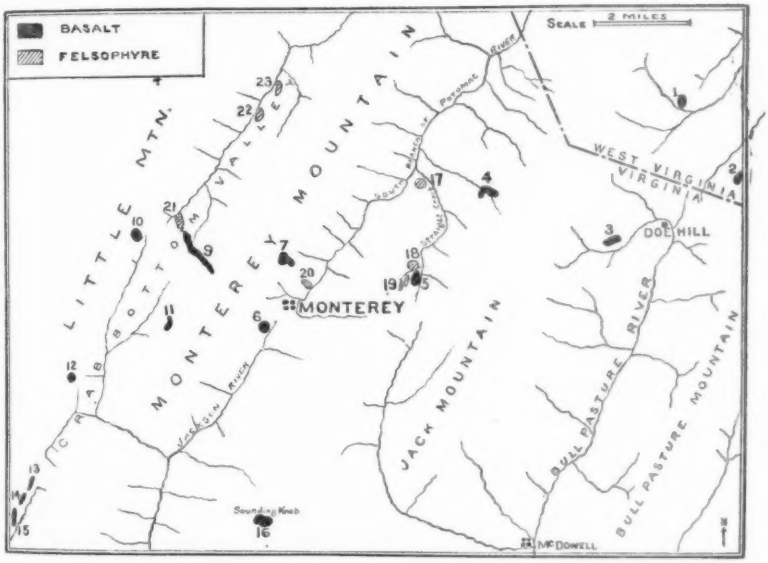


FIG. 1.—Map of a portion of central Appalachian Virginia showing location of dikes.

In 1896 I had opportunity to extend my observations farther west and discovered‡ additional basalt dikes and a very interesting series of dikes of an acid character which Mr. Keith has found should be classified as "felsophyre." The region in which all these dikes occur is an area of about 120 square miles, lying mainly in Highland County, in the central western portion of Virginia. Two dikes were found in the adjoining portion of Pendleton County, West Virginia. The region is in the

* Published by permission of the Director of the U. S. Geological Survey.

† This Journal, vol. xxxix, pp. 269–271, with petrographic notes by Mr. J. S. Diller.

‡ Announced at meeting of Geological Society of America, Dec. 28, 1896.

center of Appalachian uplift which in the Crabbottom valley west of Monterey attains unusually great altitude.

The distribution of the rocks of each of the two principal varieties is shown in Fig. 1.

The basaltic rocks at Nos. 1, 2, 3, 4 and 6 were described in the publication above referred to. They are all small dikes, Nos. 2 and 4 cutting Lewistown (Heldersberg) limestone, and No. 5 rising at the contact of Romney shale (Marcellus) and Monterey (Oriskany) sandstone. Nos. 4 and 5 are associated with friction breccias composed of a variety of more or less altered sedimentary rocks. The other dikes of basalt discovered in 1896 are of similar character but some of them are of larger size. The outcrop No. 16 at Sounding Knob is on the top of a high anticlinal mountain of Tuscarora (Medina-Oneida) quartzite, the igneous rock rising as a steep-sided neck about 80 feet above the crest line. The altitude of its summit is nearly 4,500 feet. The outcrop No. 9 is a dike which extends down the west side of Monterey mountain in the great Crabbottom anticline cutting through Martinsburg (Hudson) shale and Shenandoah (Lower Ordovician-Cambrian) limestones. Its width varies from 30 to 120 feet and its course is nearly due northwest. The dikes Nos. 13, 14, and 15 are along probably one line of intrusion trending northeast, but they appear not to be connected at the surface. At No. 15 there are showings of friction breccia of somewhat altered sedimentary rocks.

The acid rocks have only been observed within a radius of a few miles from Monterey. The dikes are small and inconspicuous. The best exposure is on the upper forks of Straight Creek, three miles east-northeast of Monterey. Here the rock occurs in several large white masses rising in a low knoll with an area of only a few square yards. The material is hard, fresh, and very characteristic. A few rods sout'ı at No. 5 there is an exposure of basalt, and a short distance west are two small exposures of narrow dikes of the weathered acid rock. They are all in Rockwood (Clinton) shales. The relations of the rocks to one another in these exposures could not be determined, owing to lack of continuity of outcrops. Near the mouth of Straight Creek, at No. 15, there is a small exposure of the acid rock cutting the Monterey sandstone. The dike near Monterey, No. 20, is exposed along the roadside about a half mile northeast of the village cutting Romney shales. It can only be traced for a few yards. In the Crabbottom valley three exposures were discovered, at Nos. 21, 22, and 23, in the Shenandoah limestone along the road from Hightown to New Hampton. A half mile north of Hightown, at No. 21, two small dikes of decomposed and weathered felsophyre are seen in the roadcuts penetrating Shenandoah limestone. At Nos. 22 and 23 several other small dikes are exposed. They are

deeply decomposed. It is possible that Nos. 21, 22, and 23 are along one line of fissure. If so, it is one coincident with the crest of one of the highest anticlinals of the central Appalachian region. No. 21 appears to be in the same fissure as the basalt dike No. 9, but the continuity of the two rocks could not be traced, owing to woods and debris. Further details of the occurrence and geologic relations of these dikes will be shown in the Monterey folio of the Geologic Atlas of the United States now in course of publication by the Geological Survey.

Notes on the Petrography.

By Arthur Keith.

The eruptive rocks above described by Mr. Darton comprise two classes of very distinct nature and appearance. The first, or basic type, is similar in all respects to the basic rocks occurring in dikes and sheets in the Jura-trias sediments and to a less degree in the Paleozoic and Archean rocks. The first material obtained in this region was described by Mr. Diller.* Subsequent investigations by Mr. Darton revealed additional dikes and the existence of a second class of eruptives which are first described in this paper. This later discovered group is of a decidedly acid composition and more nearly approaches the granite-rhyolite than any of the other large rock families.

Appended is a chemical analysis of a typical sample of the acid rock, as determined by W. F. Hillebrand in the Laboratory of the U. S. Geological Survey. For comparison a partial analysis of a typical basic rock is adjoined as determined by the same analyst.

	No. 18.	No. 5.
SiO_2	69·56	43·38
TiO_2	·31	
Al_2O_3	15·52	
Fe_2O_3	1·67	
FeO	1·19	
MnO	·07	
CaO	1·20	14·02
SrO	trace	
BaO	·10	
MgO	·41	
K_2O	4·68	·56
Na_2O	4·46	1·64
Li_2O	trace	
H_2O below 110° C.	·34	
H_2O above 110°	·67	
P_2O_5	·08	
CO_2	none	
S	trace	
Cl, Fl,	not tested for	
	101·26	

*This Journal, vol. xxxix, pp. 270–271.

The percentage of silica in the typical specimen of acid rock No. 18 is seen to be entirely characteristic of granite. The same may also be said of the other chemical constituents. Silica only appears as free quartz in the groundmass, being entirely absent from the phenocrysts. The amount of it in the groundmass, moreover, is relatively small. In this feature of inconspicuous quartz, taken in connection with the trachytic aspect of the rock in the hand specimen, these acid eruptives resemble the syenite-trachyte family. The minerals, however, and the chemical proportions show that it is of the granite family, and in its name the porphyritic aspect should be recognized for a complete description. The grain of the groundmass is micro-crystalline, but since it has not the true granitic aspect, the term "granite" or its allied terms cannot be properly applied. Neither does the groundmass contain glassy portions or any matter which can be definitely stated to be felsitic, owing to the alterations of the rock due to weathering. As a whole, however, the rock is more nearly a porphyritic felsite than anything else, and should, therefore, be designated as a fine "felsophyre."

The basic eruptives exhibit no changes, either in chemical composition or in component minerals, from the usual types of the Jura-trias basic rocks.

A brief description of each of the specimens and thin sections follows, from which the variations of the rocks can be seen. The localities from which these sections are taken are shown upon the accompanying map, fig. 1 (p. 305), by corresponding numbers.

Basic Rocks.

No. 5.—This rock in the hand specimen consists of a rather coarsely crystalline aggregate in which porphyritic individuals of olivine and augite are prominent. The groundmass is fine and of a dark gray or black color. On the weathered surfaces decay has brought out the crystals of feldspar slightly. The olivines are green and yellowish brown in color and appear unaltered. The greenish color in some of the olivine is due perhaps to small replacement by chlorite. The augites are of a dark gray or blackish gray color and show fresh cleavage faces. Aside from these two porphyritic minerals and the small feldspars upon the weathered surface, no other minerals can be detected in the hand specimen.

Under the microscope this rock differs greatly in appearance from the following sections and has a very decided porphyritic character. The phenocrysts are composed of augite and

olivine; the former are of a yellowish gray color with darker, brown borders, the latter in particularly brilliant colors and frequently with sharp, crystal faces. The groundmass is very fine and consists of plagioclase, magnetite, augite, and a little olivine. In the case of the olivines, there seems to be a gradation between the coarse phenocrysts and the grains in the groundmass. Considerable numbers of magnetite crystals are included in the augites near their borders, and also appear to a limited extent in the olivine. Slight decomposition has produced stains of limonite and small growths of chlorite in the cracks of the olivine. The large percentage of magnetite in groundmass renders it comparatively opaque. This rock bears a strong resemblance to the section (No. 1) described by Diller.

No. 11.—This specimen is somewhat weathered, being taken from the surface, and contains many faces stained with iron. It is of a dull gray color and very finely crystalline. No porphyritic minerals appear and the only minerals which can be detected by the magnifying glass are here and there small feldspar laths or an occasional feldspar cleavage face.

The texture of this rock, as seen under the microscope, is uncommonly fine for the basic eruptives of this region, and the mineral composition is likewise more than usually simple. The bulk of the rock consists of a fine mass of plagioclase crystals with a marked parallel arrangement. Intermingled and in part included within these feldspars are great quantities of minute, black crystals, the majority of which are magnetite. The only other constituents which occur in any quantity are the small individuals of mica, apparently biotite, which are compressed between the feldspar crystals and many minute individuals of augite. Considerable secondary limonite is present, probably derived from the decomposition of the iron oxides. Certain very small grains have the appearance of olivine, but are difficult of determination. The chief characteristic of the rock is its high feldspathic content and the parallel arrangements of the feldspars, which indicate flow structure. No traces of glass were observed.

No. 15.—This rock is of fine grain and dark gray to black color. Weathering extends to a depth of half an inch from the surface and produces a light gray color with considerable staining of iron. At the same time the attitude and size of the feldspar crystals in groundmass is brought out by kaolinization. In the fresh portions crystal faces and cleavage planes of the feldspar are very frequent. From this groundmass porphyritic crystals of augite of considerable size stand out prominently. Smaller porphyritic crystals of olivine are present in less numbers. Fine black specks of magnetite are dotted through the

rock and appear most prominently upon the lighter weathered surfaces.

In the thin section appears the ordinary ophitic arrangement of the Piedmont diabases. The texture is rather finer than usual in these rocks. The minerals consist of a great mass of feldspar intergrown with and enclosing numerous magnetite crystals and patches. Many crystals of olivine of somewhat porphyritic appearance interrupt the ophitic structure, and around their borders the feldspar laths have a tendency to parallelism. Secondary decomposition has proceeded to considerable extent in these olivines, resulting in patches and cracks filled with chlorite and leucoxene. In many cases limonite is deposited in the same situations. Frequent small individuals of augite appear between the feldspar laths, and small, patchy individuals of calcite are also to be seen. These do not usually have crystalline outlines. One crystal of augite of somewhat prophyritic appearance is intergrown with magnetite.

No. 16.—Few macroscopic characters are well defined in this rock. It is of a dark gray color, weathering to a lighter gray upon exposure. The feldspars of the groundmass, which are extremely fine and invisible upon fresh surfaces, are brought out in the lighter gray portions affected by the weather. Porphyritic crystals of augite are sparsely distributed through the rock, and patchy phenocrysts of feldspar appear here and there in the groundmass. In one layer these have a tendency to an amygdaloidal appearance. A few scales of biotite are also to be detected. The presence of olivine is shown in the partly weathered portions by a greenish color of the rock, and also a few phenocrysts of the same mineral are sparingly distributed.

In this section the rock is holocrystalline and displays no evidence of glass. The plagioclase laths are comparatively small and their arrangement is more nearly parallel than ophitic. The body of the rock is mainly composed of these crystals. Intermingled with them are fine crystals of augite, olivine, and magnetite, the latter in unusual abundance. No additional features of interest appear in this section.

Acid Eruptives.

In the hand specimen these eruptives have a decided light gray color, which passes, in the weathered specimens, to white or yellowish white, according to the amount of decomposition of the feldspars. The texture is in general fine. The groundmass is light gray in color; from this stand out the white feldspar and the dark biotite and augite phenocrysts. Decay

first attacks the albite phenocrysts, which are kaolinized, as a rule, even in the comparatively fresh specimens. Thus two classes of phenocrysts are distinguishable among the feldspars on the hand specimens, these being the weathered albites and the clear, unaltered orthoclase. These general characteristics are shared by all of these acid eruptives thus far discovered, and the chief variations occur in the coarser or finer texture of the phenocrysts.

No. 18.—In this specimen is found the coarsest crystallization of these acid eruptives. The groundmass is of the same dove color as in the preceding rock and has an equally fine grain. The proportion of phenocrysts of biotite and feldspar is unusually great, and perhaps one-third of the rock is composed of them. The biotites appear in flat, hexagonal crystals with sharp outlines. The division of the feldspars into kaolinized and fresh individuals is strongly accented. The rounded exteriors of the fresh feldspar phenocrysts are so clear and transparent as to strongly resemble quartz; on their broken surfaces, however, the cleavage faces stand out prominently. A few phenocrysts of augite are also to be seen, but are very far inferior in numbers to the other minerals. The phenocrysts of feldspar and biotite are about equal in amount.

In the corresponding thin section the minerals are in a much fresher condition than in most of the sections and more satisfactory determinations can be made. The general appearance of the rock is the same as in the other sections, and its simple composition is admirably shown. It is seen to consist of a microcrystalline groundmass, with phenocrysts of orthoclase, plagioclase, and biotite. In the arrangement of the crystals of the groundmass no order or system is to be discovered. The phenocrysts are perhaps slightly larger and more frequent than common in these rocks, but they consist of the usual minerals, feldspar and biotite. The outlines are sharp and clear and the crystallographic planes are, in many cases, well defined. The biotite crystals are of a greenish brown color and strongly pleochroic, and occasionally they contain small portions of the feldspathic groundmass. A slight tendency to parallelism also appears in them. In one case the biotite and feldspar phenocrysts are intergrown. The feldspar in this case appears to be orthoclase. The groundmass is a microcrystalline aggregate, chiefly of feldspar, quartz, and many extremely small crystals of magnetite or ilmenite. Such of the feldspars as can be determined comprise both plagioclase and orthoclase. No traces of glass are to be seen. There appear to have been practically no disturbances of a dynamic nature in the body of the rock, as the cracks in the larger minerals are very few, and the extinctions are not wavy. One biotite crystal shows a slight

bending, as if due to some movement after its formation. In the groundmass there is a small amount of secondary chlorite in extremely small particles, and an even smaller amount of muscovite, both apparently due to decomposition by weathering.

No. 17.—This rock has the typical aspect of the acid eruptives. It consists of an extremely fine groundmass of a light gray or dove color, through which are distributed large phenocrysts of feldspar and smaller ones of biotite. The feldspar phenocrysts do not differ so greatly from the color of the groundmass as to be conspicuous. Dark scales of the biotite, however, stand out very prominently. The feldspar phenocrysts are in part bright and clear and in part kaolinized, thus separating the feldspars into two groups. The biotites are in flat, hexagonal crystals and are very sharp and clear.

No features appear in this section which were not observed in No. 18 except a slight tendency to parallelism of the feldspar crystals in the groundmass, particularly around the outlines of the phenocrysts. This is quite marked in several cases. The phenocrysts consist of biotite and plagioclase. In a few cases doubtful orthoclase appears, in which the mineral was nearly removed in the making of the section. The amount of magnetite is decidedly less than usual, and some fine chlorite, apparently derived from original biotite in the groundmass, marks the progress of decomposition by weathering. A little of the groundmass is included in the phenocrysts, but usually their outlines are sharp and perfect.

No. 19.—This specimen, like the preceding one, is badly weathered. The general gray or dirty white color of the rock is varied by the limonite stains at the surface and in the phenocrysts, and by the prominent black biotite phenocrysts. Many of the large feldspar crystals have been entirely removed, leaving only the cavities which they once filled. The biotite crystals appear as fresh and unaltered as in the other specimens examined. The phenocrysts in general are slightly smaller than in the other specimens. This is true, perhaps, of the biotite in greater degree than of the feldspars. The proportion of the rock which the phenocrysts make up is somewhat less than usual, the biotite crystals in particular being plainly fewer. One or two doubtful cases of augite were also observed.

In this slide the proportion in size between the phenocrysts and the individuals of the groundmass is considerably changed. The phenocrysts are much smaller, while the groundmass is so much coarser that most of its individuals appear distinctly as separate crystals. The two series, however, are still greatly different in size and the rock is accordingly porphyri-

tic. The phenocrysts are of the same minerals, biotite, however, being comparatively scarce. The feldspar phenocrysts also have a tendency to develop in rudely radiating bunches of stubby crystals. These are, for the most part, plainly plagioclase, but there are many doubtful instances in which it is probable that the mineral is orthoclase. Much the greater part of the groundmass consists, as before, of minute plagioclase crystals closely felted together and clamping small individuals of biotite, quartz, and the iron oxides. In the latter considerable decomposition has taken place, giving rise to limonite and limonite stains, and outlining by these colors the network of feldspar crystals. Occasionally inclusions of the groundmass are seen in the feldspars, but they are more rare than in the preceding sections. The feldspar phenocrysts are sharply outlined and the crystal faces seem to have suffered practically no resorption.

No. 21.—The material of this specimen is very badly decomposed, but owing to the striking texture of the rock, its nature is seen as clearly as in the fresh specimens. The same grayish groundmass appears, in which minute feldspar individuals can be detected by their weathering. The usual phenocrysts of feldspar and biotite are conspicuously developed and attain sizes as great as in the preceding section. Only one or two augite crystals, however, were detected. The decomposition of the ferruginous minerals has stained the exterior of the rock, and limonite has concentrated in those phenocrysts which were most thoroughly decomposed, giving them a yellowish appearance instead of the white color usual in the fresh rock.

This section is of a strongly porphyritic aspect. The phenocrysts of biotite are large and well-shaped; areas representing probable feldspar were nearly worn away in the preparation of the section on account of its weathered condition. The groundmass consists of a finely felted mass of feldspar, chiefly plagioclase, with many small crystals of biotite, ilmenite or magnetite, and a little quartz. Owing to the weathered condition of the rock, the ferruginous minerals have oxidized considerably, and stains and bodies of limonite are frequent. Portions of the feldspathic groundmass are enclosed in the biotite crystals. These latter are, for the most part, fresh and show slight decomposition to chlorite. The brown color and the pleochroism are both strong.

No. 22.—This section, like the preceding, is much weathered and deeply stained with limonite. It has also a strongly porphyritic appearance. The phenocrysts consist of plagioclase, doubtful orthoclase, biotite, and augite. The crystals are large and the outlines are sharp and clear. Included in the augite

and in the plagioclase are portions of the groundmass of greater or less size and also of biotite and magnetite. In this section decomposition by weathering has proceeded to great lengths, and the smaller feldspars in the groundmass, and to some extent the phenocrysts, have decomposed with a production of considerable chlorite, calcite, and limonite. The groundmass consists of the finely felted, holocrystalline aggregate of plagioclase, orthoclase, biotite, augite, magnetite, and calcite with a few crystals of quartz.

General Nature of the Dikes.

The general distribution of these acid and basic dike rocks in an east and west belt has been already mentioned. Beyond that rude arrangement it is difficult to decipher anything systematic. In the basic rocks, while they all have the same physical appearance, contain the same minerals, and bear a decided family resemblance to each other, there are three distinct types of texture. These are the basaltic, the diabasic, and the porphyritic textures. The porphyries appear upon the west side of Jack mountain, one of which has been described by Diller and another in these pages. The rock with the ophitic texture of diabase appears in section 15, in one of the southwestern outcrops. The remainder are intermediate in appearance between these, sometimes inclining to one type, sometimes to the other. In these also the feldspars have frequently a decided fluidal arrangement, both through the body of the section in a general way, and around the larger crystals. The same arrangement appears to some extent in the porphyritic type. Section No. 16, taken from Sounding Knob, displays the most clearly fluidal arrangement. In this area of the basalt it is evident, from the appearance of the rock mass upon the ground, that it was an old volcanic neck and was produced by an injection of considerable height. Aside from these features, there seems to be no arrangement discernible.

As the chemical analysis shows, these basic eruptives are of the same class as those which appear in direct connection with the Jura-trias sediments. Under the microscope, also, they have the same appearance and contain the same minerals. Inasmuch as these Jura-triassic eruptives in some cases pass from the Jura-trias sediments into the Silurian sediments, the occurrences here are plainly in the same line. They offer, therefore, nothing especially novel. The acid eruptives, however, constitute an entirely new class of such phenomena. They have not been observed, within the writer's knowledge, at

least in the southern Appalachians. Rocks of somewhat similar appearance have been found by the author in various portions of the Archean mass east of the Silurian sediments, but the resemblance of the two groups is not sufficient to warrant any deductions. Beyond the fact of their eruption through the Silurian sediments and their location upon the great anticlinal regions, there are no facts of distribution which throw any light upon their cause. In one case, at Hightown, the acid lava appears to occupy the same fissure as that filled in one portion by the basic lava. In this case the acid eruption may represent an opening upon the same line of weakness at a separate time, or it may occupy a fissure slightly divergent from the basic fissure, the contents of each not coming into actual contact. The exposures upon the ground are insufficient to settle this question. Considerable variations of texture appear in these acid rocks, but no system is to be observed in their distribution other than a growing fineness toward the boundary of each body. In their extremely weathered condition, as shown by Mr. Darton, they easily escape observation and they may possibly be more widely distributed than is now known.

Art. XXX.—*Diaphorite from Montana and Mexico;* by L. J. Spencer.

Diaphorite being a rare mineral known from only a few localities, it seems worth while to record two new occurrences.

A stephanite specimen from the Lake Chelan district, Okanogan County, Washington, recently acquired by the British Museum, shows crystals of dolomite, quartz, galena, pyrargyrite and diaphorite. On a measured crystal of diaphorite the following forms were noted: a, b, m, π, x, ψ, y, ω and (212).

The Mexican crystals of diaphorite from Santa Maria de Catorze, in the state of San Luis Potosi, are associated with crystals of miargyrite, dolomite, quartz, pyrites and blende; they are very rich in faces and several new forms have been noted.

Except for the lamellar twinning sometimes present on freislebenite, the three minerals andorite, diaphorite and freislebenite are very similar in appearance, and can only be distinguished by measuring the crystals. Between them an interesting morphotropic relation exists, which reminds one of the relation between humite, chondrodite and clinohumite.

		Sp. gr.	Chem. comp.
Andorite	$\frac{3}{4}b : a : c = 0{\cdot}9846 : 1 : 0{\cdot}6584$	5·35	$RS . Sb_2S_3$
Diaphorite.....	$2a : b : c = 0{\cdot}9839 : 1 : 0{\cdot}7345$	5·9	----
Freieslebenite..	$\frac{5}{8}a : b : c = 0{\cdot}9786 : 1 : 0{\cdot}9277$; $\beta = 87° 46'$	6·3	$5RS . 2Sb_2S_3$

The vertical axes are in the ratio 9 : 10 : 13. The same relation can also be extended, though less perfectly, to stibnite on the one side, and to bournonite, etc., and galena on the other. This suggests that in composition also diaphorite should fall between andorite and freislebenite. Brongniardite,* which has an intermediate formula, namely $2RS . Sb_2S_3$, agrees in specific gravity and in its external characters with diaphorite: it therefore seems highly probable that brongniardite and diaphorite are identical. It is hoped to be able to collect sufficient material (measured crystals of diaphorite) for analysis, in order to definitely prove the identity here suggested.

British Museum of Natural History.

* The so-called cubic crystals of brongniardite have recently been shown to be stanniferous argyrodite (Min. Mag., 1898, xii; p. 5).

Art. XXXI.—*On the Detection of Sulphides, Sulphates, Sulphites and Thiosulphates in the presence of each other;* by Philip E. Browning and Ernest Howe.

[Contributions from the Kent Chemical Laboratory of Yale University—LXXIV.]

Some three years ago R. Greig Smith* published a method for the detection of sulphates, sulphites and thiosulphates in the presence of each other, which promised much toward the solution of this most difficult problem. The method may best be described in the author's own language: To a solution of the salts of the above mentioned acids "barium chloride is added in excess, together with a good quantity of ammonium chloride, which, like many salts of ammonium, potassium and calcium, acts as a flocculent or coagulant, and facilitates the filtration of the barium sulphate. Hydrochloric acid is next added, drop by drop, until it is evident that there is no further solution of barium sulphite and thiosulphate, and that only the sulphate remains undissolved; the solution is then filtered through a moistened double filter paper, which should be free from 'pin holes.' The filtrate will probably be clear, but if not it should be returned to the filter for a second filtration. When too much thiosulphuric acid is present, the clear filtrate will visibly become clouded, or from being whitish will become more opaque; if this occurs the solution should be thrown out, and a fresh portion made more dilute. A solution of iodine is added to half of the filtrate until the color is of a permanent yellow tinge; a white precipitate indicates the presence of a sulphite which has been oxidized by the iodine to sulphate. In the absence of a decided precipitate traces of sulphite may easily be detected by comparing the treated and untreated halves of the filtrate—a procedure which very often saves a good deal of time, as it is unnecessary to wait until a clear filtrate is obtained. The two halves are mixed, and if the yellow color disappears more iodine is added, the solution filtered and the filtrate divided into two halves as before. With a slight turbidity filtration may be omitted. Bromine water is added to one of the halves when any thiosulphate in the original solution shows itself as a white precipitate of barium sulphate, readily seen on comparing the two test tubes. The thiosulphate is by iodine converted to tetrathionate, which is oxidized by bromine water to sulphate." Three objections to this method as described will readily occur to the reader: first, the readiness with which the thiosulphate is decomposed by free hydrochloric acid; second, the comparatively large

* Chem. News, vol. lxxii, 39.

amount of acid necessary to effect the complete solution of the barium sulphite and thiosulphate when precipitated with the sulphate as compared with the amount required to prevent the precipitation ; third, the lack of delicacy necessitated by a comparison of portions of a colored solution in looking for small precipitates. The work to be described was undertaken to overcome these difficulties and to test the accuracy of a modified method. Solutions of potassium sulphite and sodium thiosulphate were made approximately decinormal and standardized in the usual manner against an iodine solution of known value. It was found that by making a solution containing sulphates, sulphites and thiosulphates very faintly acid, the sulphates and thiosulphates were held completely in solution when the barium sulphate was precipitated. The extreme sensitiveness of a thiosulphate to the decomposing action of free hydrochloric acid suggested the possible substitution of acetic acid to hold the sulphites and thiosulphates in solution. This being a weaker acid, we hoped to avoid the decomposition of the thiosulphate into sulphur and sulphurous acid, or at least to delay the decomposing action. The results of these experiments appear in the following table :

TABLE I.

	Volume cm^3 of water.	Hydrochloric acid (1 : 4) drops.	Acetic acid. drops.	$Na_2S_2O_3$ taken. grm.	Result.
1	10	2	--	0·01	No sulphur in 20 minutes.
2	10	2	--	0·1	Sulphur in 45 seconds.
3	100	3	--	0·1	Sulphur in 15 minutes.
4	10	--	8	0·01	No sulphur in 20 minutes.
5	10	--	8	0·1	Sulphur in 90 seconds.
6	100	--	10	0·1	No sulphur in 20 minutes.
7	100	--	10	0·25	Sulphur in 15 minutes.
8	100	--	10	0·5	Sulphur in 60 seconds.
9	100	--	10	1·0	Sulphur in 30 seconds.

From these results it would seem that the decomposition of a thiosulphate is more rapid in presence of hydrochloric acid than in presence of a much larger amount of acetic acid.

Our next experiments were directed toward a determination of the effect of adding stannous chloride to bleach the color of the free iodine and bromine used in the oxidation and of acidifying with acetic acid, before treating with barium chloride. That is to say, the process as we used it, consisted in acidifying the solution to be tested with acetic acid, adding barium chloride, filtering to remove precipitated sulphate (always present in the sulphite), adding iodine to the filtrate until the color was permanent, bleaching with stannous chlor-

ide, filtering off the sulphate which represents the sulphite originally present, adding bromine in excess to the filtrate and again bleaching with stannous chloride to increase the visibility of the sulphate which now represents the thiosulphate originally present. The details of experiments in which the sulphite was taken alone and oxidized with iodine are given in Table II.

TABLE II.

	K_2SO_3 taken. grm.	Volume of water. cm^3.	$BaSO_4$ precipitated after oxidation with iodine.	Remarks.
(1)	0·1	10	Very abundant	Plainly visible before adding $SnCl_2$.
(2)	0·01	10	Abundant	Plainly visible before adding $SnCl_2$.
(3)	0·001	10	Distinct	More distinct after adding $SnCl_2$.
(4)	0·0005	10	Fair	Hardly visible before adding $SnCl_2$.
(5)	0·0001	10	Faint	Invisible before adding $SnCl_2$.

A corresponding series of experiments was made in which hydrochloric acid was substituted for acetic acid and essentially the same results were obtained.

A similar series of experiments was made to test the effect of treating the thiosulphate in an acidified solution, first with iodine and then after filtration (if a precipitate had formed) with bromine. In the experiments of division A hydrochloric acid (a few drops) was added before treating with barium chloride, and in those of division B acetic acid was used similarly. Stannous chloride was employed to bleach the excess of iodine and bromine.

TABLE III.

	$Na_2S_2O_3$ taken. grm.	Volume of water. cm^3.	$BaSO_4$ precipitated by action of iodine.	$BaSO_4$ precipitated by action of bromine.	Remarks.
			A.		
1	0·1	10	Distinct	Abundant	Sulphur separated in 30 seconds.
2	0·01	10	Faint	Abundant	No sulphur in 90 seconds.
3	0·001	10	None	Distinct	No sulphur in several minutes.
4	0·0005	10	None	Faint	No sulphur; $SnCl_2$ necessary.
5	0·0001	10	None	Very faint	No sulphur; $SnCl_2$ necessary.

B.

1	0·1	10	Faint	Abundant	No sulphur separated in 1 min.
2	0·01	10	None	Abundant	No sulphur separated in several minutes.
3	0·001	10	None	Distinct	No sulphur.
4	0·0005	10	None	Faint	No sulphur; $SnCl_2$ necessary.
5	0·0001	10	None	Very faint	No sulphur; $SnCl_2$ necessary.

From these experiments the advantage of the use of acetic acid becomes apparent, as does also the use of stannous chloride in increasing the delicacy of this indication, so that a small fraction of a milligram may easily be detected.

If relatively large amounts of thiosulphate are present with small amounts of sulphite, we have sometimes found it advantageous to manipulate so that even the slow decomposition of the thiosulphate by acetic acid may be avoided by first attempting precipitation with barium chloride in a dilute ammoniacal solution. By this method the barium sulphate and sulphite are separated from the thiosulphate and identified—the sulphate by its insolubility in dilute hydrochloric acid, and the sulphite by the action of iodine upon the acid filtrate from the barium sulphate. After filtering, the thiosulphate may be detected in the filtrate by the use of iodine and bromine as described above. Table IV gives some results by this treatment.

TABLE IV.

	$Na_2S_2O_3$ taken. grm.	$BaSO_4$ precipitated by iodine.	$BaSO_4$ precipitated by bromine.	Remarks.
(1)	0·1	None	Abundant	
(2)	0·01	None	Good	
(3)	0·001	None	Fair	$SnCl_2$ necessary.
(4)	0·0005	None	Faint	$SnCl_2$ necessary.
(5)	0·0001	None	None	

As will be seen, the test for the thiosulphate by this method of treatment is not so delicate, probably on account of mechanical holding of the barium thiosulphate by the precipitated sulphate and sulphite.

Having determined the limits of accuracy of the method as applied to the sulphite and thiosulphate taken separately, our next experiments were directed toward an investigation of the

working of the method when these two acids are found together in solution. Sulphates, almost invariably present with sulphites, are of course quite easily separated by filtration and treating with the barium salt in acid solution. Sulphides if present in the solution would seriously interfere with the working of this method if not removed, being readily oxidized by the iodine or bromine to sulphite, sulphate or, should sulphur also separate, to thiosulphate. We found in course of our work that in attempting to neutralize a mixture of freshly prepared alkaline sulphide together with a sulphite we often obtained a precipitate of sulphur. After the removal of the sulphide and sulphate, we were surprised to find on treating with iodine scarcely a trace of sulphite. On treating with bromine however an abundant indication of thiosulphate was obtained. It is well known of course that thiosulphate may be found by boiling a sulphite with sulphur, but that this reaction should take place so readily and completely seemed to us rather unusual.

For the removal of a sulphide before proceeding with the tests for sulphite and thiosulphate Grieg Smith recommends the passing of carbon dioxide through the solution until the escaping gas gives no indication of hydrogen sulphide, but Bloxam* calls attention to the tedious and wholly unsatisfactory character of this method of removal and recommends a mixture of zinc chloride, cadmium chloride, ammonium chloride and ammonia. We have found that the addition of zinc acetate to a faintly alkaline solution accomplishes the same purpose in an entirely satisfactory manner. The sulphide used in our work was freshly made by passing hydrogen sulphide through a dilute solution of sodium hydroxide. When portions of this solution, still alkaline, were treated with zinc acetate in excess, and the zinc hydroxide and sulphide removed by filtration, the filtrate gave no test for either sulphite or thiosulphate by the application of iodine and bromine as described, and the vapor evolved on boiling caused no darkening of lead paper. The following table shows the results of a few experiments in which tests

TABLE V.

K_2SO_3 taken. grm.	$Na_2S_2O_3$ taken. grm.	$BaSO_4$ precipitated after oxidation with iodine.	$BaSO_4$ precipitated after oxidation with bromine.
0·1	0·01	Abundant	Good.
0·1	0·001	Abundant	Distinct.
0·01	0·1	Good	Abundant.
0·001	0·1	Faint	Abundant.
0·001	0·001	Fair	Fair.

* Chem. News, lxxii, 63.

were made for the sulphite and thiosulphate, after removing a considerable amount of the sulphide in the manner described, and of the sulphate by acidifying and adding barium chloride.

The method as we have modified it may be summarized as follows: To about $0{\cdot}1^{grm}$ of the substance to be analyzed dissolved in 10^{cm^3} of water or more, add sodium, potassium or ammonium hydroxide to distinct but faintly alkaline reaction. The solution should be neutral or alkaline rather than even faintly acid, owing to the readiness with which sulphur separates. To the alkaline solution add zinc acetate in distinct excess and filter. The precipitate may be tested for hydrogen sulphide, on acidifying, in the usual manner. To the filtrate add acetic acid, a few drops in excess of the amount necessary to neutralize, and barium chloride, and filter through a double filter. To the filtrate add iodine until the solution takes on a permanent yellow tinge, and then bleach with stannous chloride, best after adding a few drops of hydrochloric acid to prevent the possible precipitation of a basic salt of tin. A precipitate at this point indicates the sulphite. Filter, add bromine water in faint excess to the filtrate, bleaching again with stannous chloride. A precipitate on adding bromine indicates a thiosulphate originally present.

Art. XXXII.—*Twinned Crystals of Zircon from North Carolina;* by W. E. Hidden and J. H. Pratt.

The zircon crystals to be described in this paper were found at the Meredeth Freeman Zircon Mine in Henderson County, North Carolina. The mine is located near Green River and about two miles nearly south from the railroad station now known as Zirconia. This is the mine from which Gen. Thomas Clingman procured one thousand pounds of zircons as early as 1869 and which became later a large producer. The crystals occur in a saprolitic rock that was probably a biotite gneiss.

The attention of one of us was drawn to some peculiar crystals of zircon in May, 1888, by a miner who was then regularly employed in washing out zircons from the rock of this region. This miner stated that some of the men were finding "zircon-crosses" which they were wearing as ornaments, some having them "sewed to the lapels of their coats" and others "using them as watch charms." At first, no serious attention was paid to the miner's statement, for at that time it was impossible to visit the mine and verify it and besides staurolite seemed suggested by this description. Specimens of these "crosses" were received during the same month, but unfortunately they were badly broken in transit.

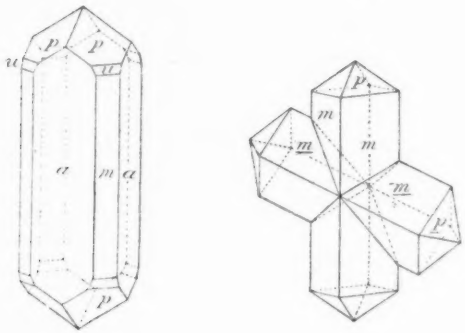
During the following summer the locality was visited by one of us, but all work had ceased at the mines. The dump was carefully searched over for the "zircon-crosses" but without success. The miners, while they well remembered the finding of these crystals, had not saved any specimens of them. The foreman, Mr. Edward H. Freeman, had fortunately preserved a small collection of different crystals found at this mine and it was from this collection that the crystals described in this paper were selected. Mr. Freeman stated that the "zircon-crosses" were obtained from only one portion of the mine and that some were found about $1\frac{1}{2}$ in. long by $\frac{3}{8}$ in. thick. He also said that they were very easily broken if carelessly handled.

All the zircon from this region occurs as crystals which vary in size from 1^{mm} to 30^{mm} in the direction of the c axis and from 1^{mm} to 25^{mm} in that of the horizontal axes. The color varies from gray to grayish and reddish brown.

The common type is the prism of the first order, m, 110, terminated by the unit pyramid of the same order, p, 111. A few crystals have been observed with the prism terminated by the steeper pyramid, u, 331 alone and also a combination of

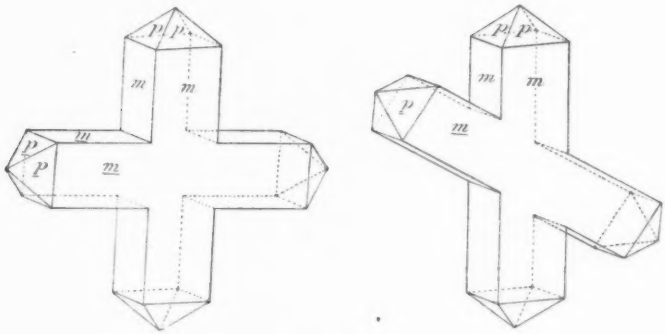
this form with the unit pyramid. Rarely the crystals have the ditetragonal pyramid *x*, 311, in combination with the unit pyramid. Fig. 1 represents one of a rarer type of crystals which is a combination of the prisms of both orders, *m*, 110 and *a*, 100, terminated by the unit pyramid, *p*, 111 and the more acute pyramid *u*, 331.

1. 2.



The only type of twinning heretofore known for zircon* is that with *e*, 101 as twinning plane, forming geniculations like those of rutile and cassiterite. The same law of twinning was observed on the Henderson County zircons, but the crystals are cruciform as shown in fig. 2.

3. 4.

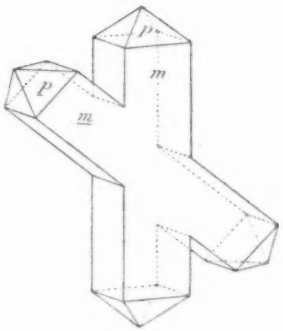


* This Journal, xxi, 507, 1881, Hidden; Phil. Mag., xii, 26, 1881, Fletcher; and Dana's Mineralogy, sixth edition, 1892, p. 486.

Besides this type the Henderson County zircon exhibits a series of twin crystals in which the twinning planes are parallel to pyramids of the first order. Five new twinning planes have been identified by us. Of these, four are parallel to the pyramidal faces, p, 111; d, 553; v, 221 and u, 331, and are represented by figs. 3, 4, 5 and 6 respectively; the fifth is parallel to the pyramid ϕ (774).*

The twin crystals are usually well developed and doubly terminated, the faces being somewhat vicinal but with sharp edges, thus enabling the faces and twinning planes to be

5.



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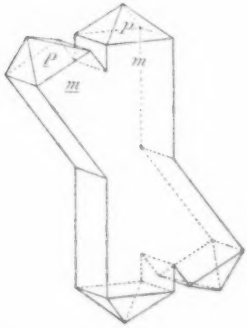


readily identified by means of the contact goniometer. The measurements were very satisfactory and close to the calculated angles, as shown in the following table:

Twinning planes.	Measured angles $m \wedge \underline{m}$.					Calculated angle.
p (111, 1)	95° 10′;	96° 30′	95°	Average	95° 33′	95° 40′
d (553, $\frac{5}{3}$)	112 10 ;	113 20′;	111 40′	"	112 23	112 50
ϕ (774, $\frac{7}{4}$)	116 30 ;	116 ;	115° 30′; 115° 15′	"	115 49	115 30
v (221, 2)	121 30 ;	122 30		"	122	122 12
u (331, 3)	138 ;	139° 10′;	140 ; 139° 30′	"	139 10	139 35

The re-entrant angle formed by $m \wedge \underline{m}$ over the twinning plane is the same as the angle of divergence of $c \wedge \underline{c}$. These prismatic edges being very sharp, the re-entrant angle could be measured very accurately with the contact goniometer, the measured angles agreeing within half a degree of the calculated angles.

The minerals associated with the zircon are the following: Pyrite, in cubes partially changed into limonite; fluorite, pale

* Dana's Mineralogy, sixth edition, 1892, p. 482.

purple etched fragments; quartz crystals; ilmenite, in minute grains (rare); small octahedrons of magnetite; orthoclase; massive garnet; parallel growths of auerlite upon unaltered gray and brown zircon; very good crystallized green epidote; allanite in masses, as large as 50 pounds; well crystallized brown sphene, most of the crystals are altered to xanthitane; and vermiculites with broad foliæ often four to six inches in diameter.

The thanks of the writers are due to Mr. Freeman, who generously presented the crystals used in the preparation of this paper.

ART. XXXIII.—*Note on the Brachiopod Fauna of the Quartzitic Pebbles of the Carboniferous Conglomerates of the Narragansett Basin, Rhode Island;* by CHARLES D. WALCOTT.

THE first notice we have of the fossiliferous pebbles of the Carboniferous conglomerates of the Narragansett Basin is by Professor Wm. B. Rogers, who in 1861 announced the discovery by Mr. Norman Easton of pebbles carrying fossils of the Potsdam fauna in the Carboniferous conglomerate north of Fall River, Mass. Professor Rogers thought the forms distinctly recognizable to be Lingula of two species, *L. prima* and *L. antiqua* Emmons.*

In 1875 Professor Rogers announced the discovery of impressions suggestive of the fossil Lingulæ mentioned by him from Fall River in the pebbles in the conglomerate at Newport, Rhode Island.† He thought that the pebbles were derived from rocks probably closely connected in time with the Braintree Paradoxides beds.

During the past two or three years Professor N. S. Shaler and Mr. J. B. Woodworth have been sending me fossiliferous pebbles picked up on the beach on the northern shore of Martha's Vineyard, and at several points along the shore of Narragansett Bay. Among these I find remains of two large Linguloid brachiopods which appear to be identical with *Obolus* (*Lingulobolus*) *affinis* Billings and *O.* (*L.*) *spissus* Billings, from the Lower Ordovician rocks of Great Belle Island of Newfoundland. The material is somewhat imperfect, but in comparing it with the series of specimens from the typical locality in Newfoundland, the two species appear to be present. There is also a new species, which I have named *Obolus* (*Lingulella*) *rogersi*, which occurs both in the quartzitic pebbles in the Narragansett Basin, and with *O.* (*L.*) *affinis* and *O.* (*L.*) *spissus* in Newfoundland.

The geologic horizon of the sandstones on Great Belle Island which carry the brachiopods is not far above the shales carrying an Upper Cambrian fauna. It is quite probable that the horizon represents the passage beds between the Cambrian and Lower Ordovician.

The exact locality from which the quartzitic pebbles of the

*The Fossiliferous Pebbles of the Potsdam and Carboniferous Conglomerate North of Fall River, Mass.; Boston Soc. Nat. Hist. Proc., vol. vii, 1861, pp. 389–391.

†On the Newport Conglomerate; Boston Soc. Nat. Hist. Proc., vol. xviii, 1875, p. 100.

Carboniferous conglomerates were derived is not, and probably will not be known. The fact that Great Belle Island is the only locality at which this peculiar group of brachiopods has been found points strongly to that region as the probable source of the fossiliferous pebbles of the conglomerate. If so, this strengthens the view of Professor Shaler that the conglomerates are of glacial origin, as it is evident that no other means of transportation than the glacier would carry pebbles of the size of those in the conglomerate so great a distance as that from the St. Lawrence Valley to the Narragansett Basin.

No other fossils have been found in the pebbles other than the brachiopods.

Art. XXXIV.—*The Origin and Significance of Spines: A Study in Evolution;* by Charles Emerson Beecher.

[Continued from page 268.]

VII. *By repetition.* (B_2.)

Under the consideration of spine production by repetition, it is proposed to include local repetition or duplication of spines on or about a primary spine, the limit of this repetition resulting in a generally spinose condition.

It has been shown that intermittent stimulus produces growth, and furthermore that growth can only take place with proper nutrition. Under local stimulus, the currents of the circulation or forces of nutrition are set up in an organism toward the center of stimulation. The nutrient matter is brought to this point, and more or less of it is expended in building up a structure which is the reciprocal or direct resultant of the stimulus. Now, since all motion is primarily rhythmic,[66] and the repetition of parts an almost universal character among organisms,[5] it would appear that the foregoing conditions would be favorable to the repetition or reproduction of the structures. In this way, it is easy to account for the growth of spines that cannot be explained as the direct result of external stimuli (A), or by any process of decrescence (C, D). The nature of the influence seems to be similar to induction in electrical physics, or to the force or stimulus of example in human conduct.

Stated as a concrete case, a simple spine produced by any primary cause may be taken, and it will be granted that the vital or physiological adjustments produced in its growth and maintenance have brought about or induced an harmonic condition in the adjacent tissues. Subsequent growth will most naturally repeat the previous structures, so that in addition to the primary spine, there will be other smaller spines on or about it, together constituting either a compound spine or a group of spines.

Carrying this repetitionary process to a maximum, there would result a generally spinous condition. As a possible illustration of this, no class of organisms probably exhibits so many kinds and series of repetitions of all sorts of external structures as the Echinodermata, and it is significant that this is a typically spiniferous sub-kingdom.

Except in a few classes of organisms, compound spines are relatively rare as compared with simple spines. They are very common among the Radiolaria, which furnish the greatest complexity occurring anywhere in the organic world. (See Plate

I.) They are also quite frequent among the Echinoidea, but more rare among the Asteroidea and Crinoidea.

Compound antlers are especially characteristic of the modern Deer family, though compound horns are but rarely found elsewhere among the mammals. The Prong-horn Antelope of America is the only living species of hollow-horned ruminant having this character. It, of course, is not intended that extra pairs of horns, which being separate, and often originating on different portions of the skull, should be considered as compound horns in the sense employed here. Likewise compound spines arising through suppression of organs or structures are not to be included here, as the compound thorns on the Honey-locust representing aborted branches.

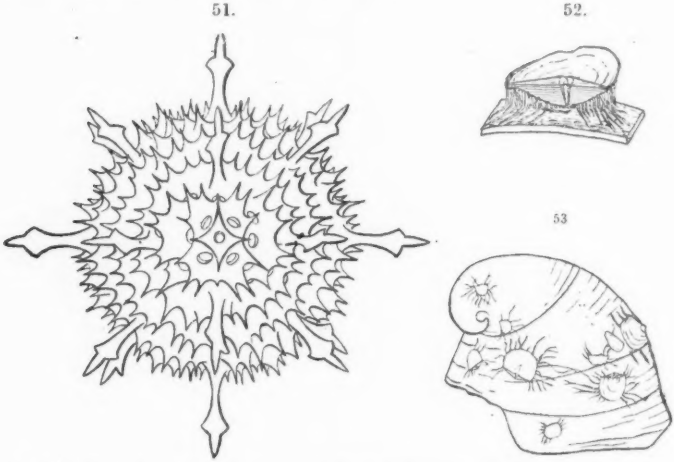


FIGURE 51. *Acontaspis hastata.* A Radiolarian, showing multiplication of spines by repetition. × 200. (After Haeckel.)

FIGURE 52. *Strophalosia keokuk.* An attached Brachiopod, showing the spines extending from the ventral valve to and along the surface of attachment. × 2.

FIGURE 53. A Gastropod shell (*Platyceras*) to which are attached a number of *Strophalosia keokuk.* Natural size.

The fin-spines of fishes are often compound, and sometimes are made up of several elements as in the spines of *Edestus* (*E. vorax*). Quite a number of Mollusca develop compound spines, as in many species of *Spondylus* and *Murex*. They are also not uncommon among the Crustacea and Insecta. Compound spines are infrequent in the Brachiopoda, being developed in but few species (*Spirifer hirtus*[31]). The Foraminifera also present but few examples (*Polymorphina Orbignii*[9]).

A number of generally or highly spinose types will now be noted to illustrate the limits of the repetition of spiny structures, the first spines having probably arisen through the operation of some primary cause, and the derived or secondary spines being produced, it is believed, by the law of repetition.

The Radiolaria have already been frequently mentioned, but as they are the most spiniferous of all classes of animals, and represent the highest degree of spine differentiation attained (figure 51 and Plate I), another brief notice will be of interest. These spines furnish characters of high taxonomic value, although generally speaking they seldom have more than specific importance among other classes. The Echinoidea and Asteroidea must also be noticed in this connection, though from the nature and origin of their spines, they do not conform to the mode of spine growth in other classes.

Productus, *Productella*, *Strophalosia*, *Aulosteges*, and *Siphonotreta* represent highly spinose genera among the Brachiopoda. *Strophalosia* is a form in which the ventral valve is cemented to some object. Whenever the valve rises well above the object of support, the spines are free like those frequently present on the dorsal valve; otherwise the spines extend root-like along the supporting surface (figures 52, 53).

Aulosteges presents a still further tendency to complete spinosity, for not only are both valves covered with spines, but the deltidium also.

Spondylus (figure 30) and *Murex* are well-known types of very spiny forms of Mollusca. *Acidaspis*, *Terataspis*, etc., hold the same place among the Trilobita; *Echidnoceras*, *Lithodes*, etc., among the Decapoda; and the Spiny Box-fish (*Diodon*), Pipe-fish, etc., among the Pisces. The higher animals also furnish examples of extreme spinosity, as in the Horned-Toad (*Phrynosoma*), the genera of Ceratopsidæ, gigantic Cretaceous Dinosaurs, and the Echidna and Porcupine.

All these forms present numerous spines, some of which cannot be explained as having arisen directly from external stimuli, for they are in comparatively well-protected regions out of the way of external stimuli. Neither can all of them serve for offense and defense, as they are often not located in the most advantageous positions; nor are they differentiated out of any previous ornaments or special structures. In fact, no factor of spine genesis except the one of repetition seems to be sufficient to account for their development.

VIII. *Restraint of environment causing suppression of structures.* (C_1.)

The previous categories of spine production (I–VII) have been brought about by some process of growth or concrescence

through external and internal agencies. There still remain for discussion the formation of spines by processes of decrescence caused by extrinsic restraint (C), or intrinsic deficiency of growth power (D). The lack of vitality or growth force generally stands so directly as the result of an unfavorable environment, that it is often difficult or impossible to distinguish between their action. Furthermore, as in the case of many parasites, it may be seen that the environment may be quite favorable as regards temperature, nutrition, etc.; but unfavorable in respect to motion and use of sensory and motive organs. From the almost universal degradation and retrogression of parasitic forms, it is necessary to consider these as intrinsically deficient, and therefore lacking in the qualities of growth force which normally favor a progressive evolution. Here, also, there are apparently two intimately associated causes. In an attached animal, the absence of stimulus from disuse of an organ tends toward atrophy, and the retrogressive development serves to affect many organs in the same manner. The direct and indirect results of the restraint of the environment may therefore be expected to shade imperceptibly into each other, with only the extremes sufficiently distinct for separation.

The influence of an unfavorable environment as effecting the character and growth of plants and animals is well shown in desert or arid regions, and the flora has been made the subject of especial study by Henslow.[33] In such regions, the first thing to impress the observer is the small size of the species. Next to diminutive size, the scantiness of life is a striking feature, for large areas are common in which life is almost wanting. An examination of these plants reveals a series of characters not usually present elsewhere, among which may be mentioned the development of a minimum amount of surface, constituting what is known as consolidated vegetation; next their uniform gray color, due either to excessive hairiness or a coating of wax; and lastly, their frequent spinescent characters.

The spines on desert plants are a feature of such general occurrence that it has led to the notion that vegetable spines are always associated with unfavorable conditions and are therefore suppressed structures. This is probably incorrect, for in plants as in animals, spines may be developed by the progressive differentiation of previous structures; as in the angular edges of the leaf-stems of many Palms becoming spiniferous; or, as will be shown, suppressed structures may arise from deficiency of growth force. In all cases, spines may or may not serve for protection. Thus, while they are not always an indication of unfavorable environment, those occurring on desert plants may generally be so considered, for they are

developed out of structures which are normally of vital physiological importance.

An animal or plant having spines and living in a favorable environment, involving freedom of motion for animals, and abundance of nutrition without extremes of temperature or dryness for both animals and plants, will, it is believed from the discussions and analyses of spine genesis in its various phases, develop these features in most instances, without the sacrifice of organs and structures having important physiological and motor functions. Thus, ordinarily, among animals it is found that spines arise as excrescences or outgrowths of exoskeletal or epidermal tissues, without seriously affecting the function of the organ or organs upon which they are located. Such cases may clearly belong to the most progressive series, and in fact usually occur there.

On the other hand, if it is found that a leg, a wing, a digit, or other organ is developed into a spine, this is always accomplished by a process of retrogression, resulting in the greater or lesser suppression of the part in question. It is also seen that this kind of spine occurs most frequently in retrogressive series or in others showing arrested development, and the necessary interpretation seems to be either that the environment is or has been unfavorable, at least so far as the particular organ or set of organs is concerned, or that the vital power has declined. Both influences are intimately associated, and the latter is often the direct result of the former.

The stunting effects of aridity and barren soil on our common plants is familiar to all. Among the plants of the desert is found every evidence of similar stunting combined with adaptations to resist the unfavorable conditions of deficient water supply, excess of radiation, etc. The diminution in size applies not only to stature, but to the leaves and branches, especially the parenchymatous tissues or parts of the plant engaged in aëreal assimilation. Consonant with these changes, the drought and other conditions produce a hardening of the mechanical tissues, which is of great aid in resisting the extreme heat and dryness of the desert. Sometimes a deposit of wax affords a similar protection.

The reduction of the leaves takes place in various ways. They may simply become smaller in every dimension and finally be reduced to mere scales, or an aphyllous condition may be established. They may grow narrower and narrower until only the hardened veins or midrib remains; or leaves may be developed only for a short time, and, in the case of compound leaves, after the shedding of the leaflets, a spiniform leaf axis remains, as in *Astragalus Tragacantha*[35] (figures 55, 56). The suppression of branches tends towards the same end;

namely, either to their complete disappearance or to their partial suppression into hard spiniform processes or thorns. Thus, both leaves, branches, and other parts of the plants may become reduced to their axial elements, bringing about what is commonly termed spinescence.

The spiny character of these plants is therefore one of the results of an arid environment, and it may or may not be of sufficient frequency to give an especial character to a particular desert flora. There is, moreover, a secondary influence which has an effect in determining the abundance of spinose plants in desert as well as in many other situations. This relates to the destruction of the edible unarmed species by herbivorous animals, and the comparative immunity of the spiny types. Thus, in old pastures, the prevailing flora is apt to be one that is offensive to grazing animals. This character is generally given by poisonous plants or those having a disagreeable flavor, or by those whose form or spiny structures afford protection.

This secondary influence by grazing animals may have had some effect in determining the particular abundance of spiny plants in certain desert regions, and their comparative infrequency in other similar regions. In either case, the unfavorable environment brings about a suppression of structures, and one type of this action results in the production of spines. These represent the limits of retrogression before the part becomes entirely obsolete.

Wallace has criticised Henslow's views on the origin of xerophilous plants and their distribution. It is believed that the views here offered remove some of the objections, and bring the opinions of these authors into greater accord.

Under arid conditions, bracts, stipules, leaves, and even branches may become spinescent. Some forms in which the spinose character has not as yet become permanently fixed by heredity, when transported or found living in moister and richer soils, develop normal leaves or branches, and lose their spinescence; others, like the Cactus, retain their spines under similar changes; while still others, as *Acanthosicyos horrida*,[33] cannot be artificially cultivated, and have become truly xlerophilous types.

As examples of plants which lose their spines by cultivation, the Pear, species of Rose, Plum, etc. (Henslow), may be cited. According to Henslow,[33] others, as *Onomis spinosa*, have an especially spiny variety (*horrida*) living on sandy sea-shores, while in more favorable natural situations, the same plant becomes much less spiny, and under cultivation loses its spines. M. Lothelier[42] also found that by growing the Barberry (*Berberis vulgaris*) in moist air, the spines disappeared, the parenchyma of the leaves being well formed between the ribs and

veins. Dry atmosphere and intense light both favored the production of spines.

Henslow[33] cites the genus *Zilla* as a desert plant in which the branches are transformed into spines, *Echinops* for a similar modification of the foliage, *Fagonia* for spiniform stipules, and *Centaurea* for spinescent bracts. As further illustrations taken not only from desert plants but also from others commonly found in dry, rocky, or unfertile situations, the following examples may be taken, some of which are familiar cultivated species. The stunting of branches into spines is common among neglected Pear and Plum trees, and is a normal character in the Hawthorn, Honey-locust, *Cytisus* (figure 54), *Vella*, etc. Leaves transformed into spines are characteristic of the Cactaceæ of America, the columnar Euphorbiaceæ of Africa and southern Asia, and are also familiar in the half-shrubby Tragacanth bushes (figures 55, 56) so common in southern Europe, especially in the eastern portion, and in the ordinary Barberry (figure 13). Spiniform stipules are usually present in the species of *Robinia*, of which the Common Locust (*Robinia pseudacacia*) furnishes a well-known illustration (figure 57). Spiniform bracts are best known among the Thistles (*Cirsium lanceolatum*, *C. horridulum*, etc.).

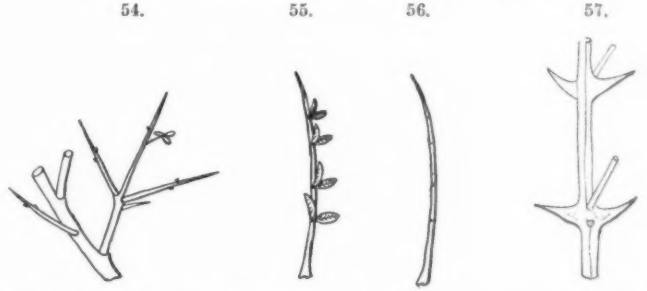


FIGURE 54. The spiny *Cytisus* (*C. spinosus*), showing suppression of branches into spines. (After Kerner.)

FIGURE 55. A single leaf of Tragacanth (*Astragalus Tragacantha*) from which the three upper leaflets have fallen. (After Kerner.)

FIGURE 56. Leaf axis of the same, from which all the leaflets have fallen. (After Kerner.)

FIGURE 57. Twig of Common Locust (*Robinia pseudacacia*), showing spines representing stipules.

As the restraint of an environment acting on an animal so generally results in the disuse and atrophy of the organs affected, most cases will have to be considered under the head of disuse. Therefore, while the environment is the primary factor, its influences are mainly exhibited through secondary or resultant conditions. In some cases, however, it is possible

to interpret a vestigial or suppressed structure directly into terms of an unfavorable environment. Thus, if the probable origin of the vestigial hind legs of a Python is considered, it leads to the belief that they represent legs which were of functional importance to some of the early ancestors of this snake. The gradual elongation of the body and the consequent change from a walking or direct crawling habit to a mode of progression chiefly by horizontal undulations, necessarily brought the legs into a relation with the environment which was unfavorable either for their function or growth. Their suppression is complete in most snakes, but in the Python, the hind legs are represented by two spurs or spines (figure 58). On the interior of the body they are supported by vestiges of femora and ilia, showing their true affinities with hind limbs. Some snake-like Batrachians (as *Amphiuma* and *Proteus*) still retain short and weak external limbs. These would undoubtedly soon be lost by a change from aquatic to terrestrial or arboreal habits.

58. 59.

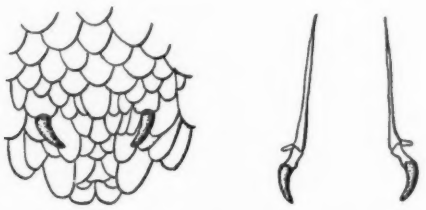


FIGURE 58. Portion of skin of Python, showing the spurs which represent the suppressed or vestigial hind legs. $\times \frac{1}{3}$. (After Romanes.)
FIGURE 59. Bones of suppressed legs of Python. All but the claw-like termination are internal. $\times \frac{1}{3}$. (After Romanes.)

In explanation of the nodes and spiniform processes on the epitheca of *Michelinia favosa*, it may be suggested that they represent aborted corallites, or attempts at budding. This coral belongs to the order Porifera, which has been shown by the writer[7] to have very pronounced tendencies toward proliferation, and on the interior of the colony, these attempts result in the production of mural pores. Most of the species of *Michelinia* are hemispherical or spherical. *M. favosa* is inclined to be pyriform in shape, rising above the object of support, and thus presenting a rather large epithecal surface. Manifestly the lower side of the corallum is unfavorably situated for the growth of corallites, and any efforts at proliferation on the part of the peripheral corallites is apt to result in stunted outgrowths. There is here a very close connection

between restraint of environment and deficiency of growth force. If the whole corallum is taken into consideration, the restraint of the environment may be taken as preventing the growth of corallites on the lower side. If one of these single stunted corallites is considered, it may be said that the deficiency of growth force through lack of nutrition caused its suppression.

IX. *Mechanical restraint.* (C_2.)

Among the factors of spine genesis, mechanical restraint is probably of the least importance. It can only rarely happen that an organism is forced to grow a spine contrary to the natural tendencies of normal development. Yet as there are occasional types of spiniform structures which can best be explained as due to the mechanical restraint of the environment, it is necessary to notice them in order to make the categories of origin as complete as possible.

The illustrations will be taken chiefly from the Brachiopoda and Trilobita. The recent Brachiopod *Mühlfeldtia truncata* is semi-elliptical in outline, and has a very short stout pedicle which holds the shell so closely to the object of support that the beak is truncated from abrasion and resorption. In specimens attached to a small branch of a coral, thus allowing the cardinal extremities of the shell to project beyond the object of support, the ends of the hinge are generally rounded. Specimens growing on a large flat surface have the cardinal extremities angular or submucronate. Similar variations are to be observed in other living species of Brachiopods (*Cistella*, some *Dallina*, etc.). Some of the extinct genera show more highly developed cardinal extremities which are often very characteristic of certain species, though considerable variation is found to exist. It is evident that these elongated hinge lines have arisen from the mechanical necessities of a functional hinge, and their greater or less extent is also to a degree dependent upon the nature of the object of support which furnishes a stimulus to the growing ends of the hinge. A marked example is shown in *Spirifer mucronatus*, with the cardinal angles extended into spiniform processes (figure 60). Similar features are presented by many other species of *Spirifer*, *Orthis*, *Leptæna*, *Stropheodonta*, etc.

60.

FIGURE 60. Dorsal view of *Spirifer mucronatus*, Devonian. Showing spiniform cardinal angles. × ⅔. (After Hall and Clarke.)

In the Trilobites, the pygidium, or abdominal portion, consists of a number of consolidated segments, and the segments of the thorax are successively added in front of this tail piece. The first thoracic segment is therefore formed between

the cephalon and pygidium, and its form is mechanically in agreement with the requirements of the animal for bending the body, and with the adjacent margins of the cephalon and pygidium. In a way, it may be said that the segment is moulded by the adjacent parts, and may therefore take its form from the cephalon (figure 61), or from the pygidium, as in the examples following:

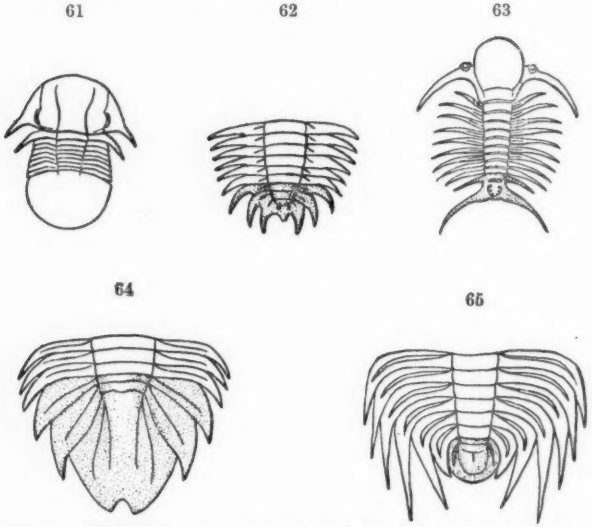


FIGURE 61. *Illænus* (*Octillænus*) *Hisingeri*, Ordovician, Bohemia. A Trilobite showing spiniform pleural extremities of first thoracic segment, corresponding to the genal spines of the cephalon. ×¾. (After Barrande[4].)

FIGURE 62. *Cheirurus insignis*, Silurian, Bohemia. Pygidium and six thoracic segments. ×¾. (After Barrande.)

FIGURE 63. *Deiphon Forbesi*, Silurian, Bohemia. Entire specimen showing spiniform pleural of segments corresponding in direction to those of the pygidium. (After Barrande.)

FIGURE 64. *Lichas scabra*, Silurian, Bohemia. Pygidium with three thoracic segments, showing spiniform ends of pleura. ×¾. (After Barrande.)

FIGURE 65. *Paradoxides spinosus*, Cambrian, Bohemia. Pygidium and six free segments. ×¾. (After Barrande.)

During growth, the new segments are added in front of the anal segment, so that after the number of abdominal segments is complete the thorax is increased by the successive addition of what in earlier moults were pygidial segments. By this means, the pygidium generally controls or determines the character of the segments of the thorax. If the pleura of the pygidium are extended into spiniform processes, the pleural ends of the segments are also spiniform, as in *Lichas* (figure 64), *Ceraurus*, *Cheirurus* (figure 62), *Deiphon* (figure 63), *Acidaspis*, *Dindymene*, etc.

Likewise, if the pleura or their distal ends are directed posteriorly nearly parallel to the axis, the mechanical necessities of motion require that the portions of the free segments pointing backward should be free, thus making the ends of the thoracic pleura generally appear as retrally curved spiniform extensions. Extreme examples of retrally directed pleura accompanied by small pygidia are shown in *Paradoxides* (figure 65), *Holmia*, *Olenellus*, *Elliptocephala*, etc. Genera having the ends only of the pleura directed backward are generally less inclined to form spiniform terminations. In contrast with these, it is found that all the Trilobites having the pleura directed outwards and with entire pygidial margins, do not ordinarily develop long pleural spines; as *Asaphus*, *Illænus*, *Agnostus*, *Phacops*, *Calymene*, etc.

The examples of the caterpillars of moths belonging to the Schizuræ, described by Packard [54] as mimicking the serrations of the leaves upon which they feed, have previously been noticed in this essay, under the head of mimetic influences. The initial cause of the spines may possibly be explained as in part due to the mechanical conditions. During their early existence the larvæ feed on the lower side of the leaves, and have no spines. Later they feed on the edges of the leaves, and at the same time acquire dorsal spines. The conformation of the animal to the serrated edge of the leaf would produce corresponding elevations and depressions on the back. The location of these would be fairly constant from the habit of the animal of feeding chiefly between the denser leaf veins which determine and terminate the serrations. The raised parts of the animal would receive the greatest amount of stimuli, and at these points spines would naturally appear.

The processes producing the spines noticed in this category (IX) are classed with others under decrescence, for the reason that the growth is restrained or controlled by mechanical necessities. If the restraint were absent, it is probable that a more expansive growth would take place or that other structures would be correspondingly benefited.

X. *Disuse.* (C_2, D_2).

In causing the reduction or atrophy of an organ, the effects of disuse have generally been recognized by most observers. In this way, the origin of many of the so-called "rudimentary organs" has been satisfactorily explained by Darwin [14] and others. Two classes of structures are evidently comprised within the common definition of rudimentary organs, namely, nascent and vestigial organs.

Nascent structures indicate the beginnings or initial stages

of organs, while vestigial structures are the remnants left after the functional suppression of organs. The suppression is usually caused by unfavorable conditions or by disuse, which produce either a retardation of growth or a retrogressive development. In both cases, the results are similar. By retardation, an organ is prevented or restrained from functional development and is therefore useless as a normal organ. By retrogression, an organ gradually reverts to an initial type, loses its function, and becomes a vestigial structure. In most instances, a change of food or habit, or the substitution of a new and functionally higher structure, causes the disuse of some organ, which, under previous conditions, was of use to the animal.

Nascent structures, or the beginnings of organs, are generally made up of active tissues that only require stimulus and nutrition to perfect their function. On the other hand, suppressed or vestigial structures are composed of comparatively inert tissue and are in consequence largely made of the mechanical elements of secretion of the organism. It may therefore be considered that true rudimentary or nascent organs are potentially active, and suppressed structures are inert. It is with the latter class, the inert, that a study of spine genesis by atrophy is chiefly concerned.

The gradual loss of function through disuse, and the consequent loss of nutrition with the concomitant rapid decrescence of active tissues, brings about a change in the ratio of active and inert structures. The progression of this process naturally results in the production of a structure having a maximum of inert or mechanical tissues, and a minimum of active constituents. Moreover, it has already been shown that the axial elements are the most persistent, and therefore the last to disappear; also that the peripheral appendages and outgrowths of any organ first show the action of decrescence. Evidently, the conditions here described are favorable for the production of spines out of an organ primarily possessing distinct active functions. The axis of an organ gives the necessary form, and the hard tissue the structure, so that the whole will conform to the definition of a spine given early in this paper; namely, a stiff, sharp-pointed process.

The restraint of the environment was found to be one cause for decrescence of organs. Another, which is properly the subject matter of the present section, is disuse; and lastly, it will be seen how the deficiency of growth force may bring a similar suppression of structures.

There is considerable difficulty in selecting particular examples which will conform clearly to the strict requirements of these three categories. In a certain sense, some of the exam-

ples of spines produced by decrescence may belong to more than one category. However it does not prevent the acceptance of any one of the three as primary causes. Thus, it may be urged that disuse has caused the atrophy of leaves into spines among many desert plants, or produced a similar reduction of the limbs in a Python. While this may be true from one point of view, yet the manifest unfavorableness of the evironment in both, seems to be a sufficient reason for making it the primary factor. On the other hand, many parasites showing similar atrophies are not dependent upon a large number of active organs for their food and maintenance. After finding a host, an abundance of food is at hand, and the environment may be considered a favorable one. All the organs, except those of nutrition and reproduction, then become more or less useless and dwindle away, leaving vestigial organs, or disappearing altogether. Furthermore, a change of habit, as from climbing to flying, will necessarily cause the atrophy of some of the structures used for climbing, and the hypertrophy of others for flying.

Most of the examples illustrating the production of a spine through the atrophy of an organ by disuse are to be found in the legs and digits of animals. The process bears considerable resemblance to the formation of spines on many plants by the suppression of leaves, branches, etc. They will be noticed here, although properly these vestigial structures among animals are more strictly of the nature of claws, or at the most, spurs.

Many parasitic plants, especially among the Balanophoreæ, are reduced to a simple stem bearing the inflorescence. The leaves are represented by scales which are often spiniform, though seldom of sufficient stiffness to entitle them to be called spines. In desert plants, many of which have a similar type of growth, the hardening of the mechanical tissues by the effects of drought has converted similar leaf structures into spines, while the parasitic plants are not normally subjected to such continuous dryness and extreme heat, and therefore the mechanical tissues seldom become hardened.

Parasitic animals, especially among the Crustacea and insects, often show a reduction in the number of joints in the legs, and even in the number of limbs themselves. The terminal claws generally persist, and are sometimes longer than the rest of the leg; as in the Itch mite, *Sarcoptes Scabei*, and in the female of the parasitic Copepod *Lernæascus nematoxys* (figure 66).

Among many aquatic Crustacea and Limuloids, the specialization and seggregation of the ambulatory and swimming appendages towards the head or anterior regions of the body have

produced a corresponding suppression of appendages on or near the extremity of the abdomen. This statement of fact is the basis of the principle of cephalization of Dana,[12] who applies it especially to the Crustacea, as follows: "There is in general, with the rising grade, an abbreviation relatively of the abdomen, an abbreviation also of the cephalothorax and of the antennæ and other cephalic organs, and a compacting of the structure before and behind; a change in the abdomen from an organ of great size and power and chief reliance in locomotion, to one of diminutive size, and no locomotive power." Audouin's law that among the Articulata, one part is developed at the expense of another, may be also noticed here as affording a further explanation of the suppression of the posterior appendages correlative with the greater development of the parts anterior to them. In a Crustacean using its tail for propulsion, as the Lobster (*Homarus*), the telson is broad and flat, and the adjacent segment has a similar development of the appendages. In other forms, as the Horse-Shoe Crab (*Limulus*) and the Phyllocarids, the tail is not used for propulsion, and at best serves chiefly as a rudder, while some of the legs on the anterior part of the abdomen or on the thorax are large and strong and are often provided with paddles. These groups, the Limuloids and Phyllocarids, show a greater or less suppression of the last abdominal appendages, and in many genera, the body terminates in a spiniform telson or tail spine. The process of suppression may or may not result in a spine. In the crabs, the abbreviated abdomen is folded under the cephalothorax, and in *Lepidurus* and *Pterygotus* the telson is a scale or plate-like organ. For the most part, however, the abbreviation of the abdomen and the suppression of its appendages have reduced the telson to a spine, as in *Limulus* (figure 67), *Eurypterus*, *Stylonurus*, and *Prestwichia* among Limuloids; and *Olenellus* among the Trilobites. In addition to a telson spine, the Phyllocarids have two lateral spiniform cercopods, the three spines together constituting the post-abdomen, as in *Ceratiocaris*, *Echinocaris* (figure 68), *Mesothyra*, etc.

Although the last abdominal segments of the Horse-Shoe Crab have lost their appendages and show evidences of suppression, yet the tail spine is a large and useful organ, for it is of just the proper length to enable the animal to right itself after being overturned, which it is unable to do with its feet alone. The process of natural selection has doubtless in this way contributed to the development and retention of the long spine. This use cannot be ascribed to the tail spines of the Phyllocarids, though they evidently were important aids in directing movement, and also offered some degree of protection.

The terminal claws on the phalanges of the wings of some

birds are nearly all that remains of the external fingers, or digits. In the Hoactzin of South America (*Opisthocomus cristatus*), the young bird has a thumb and index finger, both provided with claws, and climbs about much like a quadruped, using its feet, fingered wings, and beak. According to Lucas,[43] a rapid change "takes place in the fore limb during the growth of the bird, by which the hand of the nestling, with its well-developed, well-clawed fingers, becomes the clawless wing of the old bird with its abortive outer finger." Similar claws or spurs occur on a number of other birds, some having functional wings, as in the example just described, and others having only vestiges of wings, as in the Wingless Bird of New Zealand (*Apteryx*, figure 69).

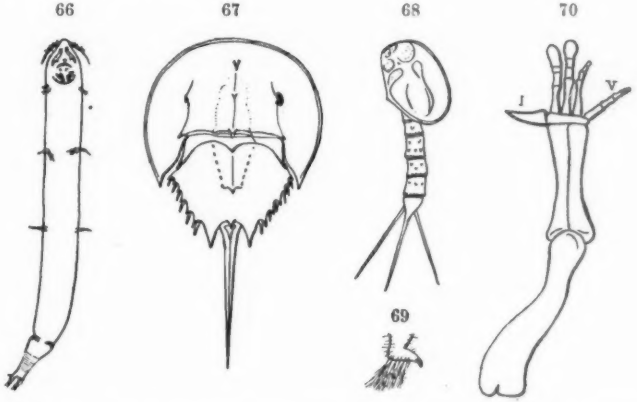


FIGURE 66. Female of *Lernæascus nematoxys*. A parasitic Copepod, showing suppression of limbs. Enlarged. (After Claus.)

FIGURE 67. Horse-Shoe Crab, *Limulus polyphemus*, showing telson spine and abbreviated abdomen. Reduced.

FIGURE 68. A Devonian Phyllocarid, *Echinocaris socialis*, showing spiniform telson and cercopods.

FIGURE 69. Wing of *Apteryx australis*. $\times \frac{1}{4}$. (After Romanes.)

FIGURE 70. Skeleton of right fore limb of the Jurassic Dinosaur, *Iguanodon bernissartensis*, showing suppressed first digit. $\times \frac{1}{10}$. (After Dollo.[16])

Another example may be taken from the Dinosaurian Reptiles. The Jurassic genus *Iguanodon*, from England and Belgium, belongs to a group (Ornithopoda) in which the number of functional digits varies from three to five in the manus, and from three to four in the hind feet. In this genus, the hind foot had three functional toes, representing the second, third, and fourth of a normal pentadactyl foot. The first is represented by a slender tarsal bone alone, while the fifth is completely suppressed. The manus, or fore foot, of this ani-

mal shows the second, third, fourth, and fifth digits of functional importance as digits, while the first is shortened and atrophied to the condition of a stout spur, standing out at right angles to the axis of the leg, as shown in figure 70. The fore legs of *Iguanodon* and others of the same order were short, and apparently used more for prehension than locomotion, and in *Iguanodon*, the suppression of the pollex, or thumb, into a spur doubtless provided the animal with a powerful weapon. Here is seen the suppression of a digit by loss of normal function, resulting in a protective structure of considerable value.

XI. *Intrinsic suppression of structures and functions.* (D_1.)

The most obvious and direct relationship between an unfavorable environment and the suppression of structures to form spines was afforded by desert plants. In illustration of the intrinsic suppression of structures by deficiency of growth force, the vegetable kingdom again seems to offer the clearest evidences of a like relation between cause and effect. Instead, however, of taking an unfavorable environment, in the present instance a favorable environment must be assumed, and then a type which expresses in various ways its deficiency of growth force must be sought.

In the desert plants, it was found that no single family exclusively constituted the desert flora, but that a considerable variety of types were present, and that some of these belonged to perfectly normal families commonly living under ordinary favorable conditions. Moreover, it was evident that there were certain types of form and habits of growth which were especially characteristic of plants living in desert or similar unfavorable regions. Therefore, to illustrate clearly intrinsic restraint or suppression of structures, it will be necessary to take an environment which, in most respects, may be considered as favorable, and also a type of plant life presenting evidences of a deficiency of growth force.

The great groups of plants commonly known as brambles and climbing plants appear to meet most of the requirements. They abound in regions where the greatest luxuriance of vegetation is found, and are therefore chiefly characteristic of the tropics. Kerner[38] estimates that there are two thousand species of the true climbing plants in the torrid zone, and about two hundred in temperate regions. Tropical America has the largest number of species, the flora of Brazil and the Antilles being especially rich. In the sombre depths of the tropical forest, the climbing plants, or "lianes," are not so abundant as in the open glades and along the edge of the forest, where the amount of light is greater and the conditions of

existence more favorable. As far as richness of soil, amount of light, and degree of temperature are concerned, it must be admitted that their environment is as favorable as that of any of the associated plants having different habits of growth. The difference between the strong and erect plants and the comparatively weak and climbing forms is therefore not an extraneous one. It resides within the plant structures themselves, and is an intrinsic character or an expression of hereditary vital forces.

The law of recapitulation demands that each individual during its development shall pass through an epitome or recapitulation of its ancestral history. In view of the fact that the young seedlings of climbing plants and brambles have the erect form and proportions of normal erect foliage stems, it is safe to infer that they have been derived from erect forms. Further evidence is afforded from the absence of climbing plants in the earlier terrestrial floras. It is obvious, therefore, that they have been developed out of erect forms by a process of degradation.

The next striking feature to be noticed in climbing plants is their extreme slenderness, due to the general suppression of the plant body. They may attain lengths not reached by the highest trees, and yet the diameter of the trunk is but a minute fraction of the length. The Climbing Palm, or Ratan, has stems of great length and tenuity. It has been stated that stems two hundred meters long have been observed having a uniform thickness of only from two to four centimeters.[38] The diameter of such a stem would be only one or two ten-thousandths of its length. The length of the internodes is another conspicuous character in climbing plants, and both this and the slenderness of the stems suggest the results obtained by growing ordinary plants in the dark, where the conditions are adverse to increased vitality.

The transfer of function from one part of the plant to another, usually by a process of retrogression or degradation, is also very common. The first growth above the ground is a leafy stalk. Later, after the plant has attained a considerable height, the lower portion puts out quantities of rootlets and loses its foliage. The rootlets may be mere dry threads or points of support for the stem; or, if they happen to encounter a crevice containing soil, they develop into true absorbent organs. In others, the ends of the growing stems or any point on the stems, upon reaching the earth, may put out vigorous roots. These facts seem to show a lack of positive differentiation throughout the plant, which admits of the substitution of a lower structure for a higher, by the suppression of a higher function.

Lastly, the general spininess of climbing plants and brambles is a well-known and conspicuous character. Kerner[38] says that "most, if not all, plants which weave into the thicket of other plants are equipped with barbed spines, prickles and bristles." These spiniform processes seem to fall naturally into two classes. First, those produced by the suppression of stipules, leaves, petioles, branches, etc., and second, those appearing as simple eruptions on the surface.

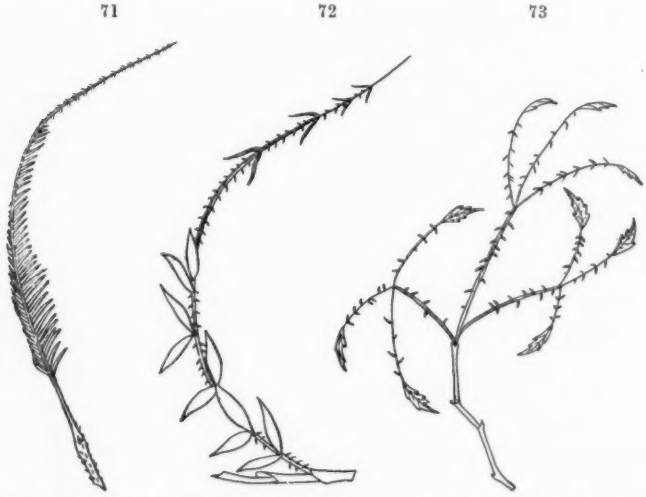


FIGURE 71. Leaf of Ratan, *Dæmonorops hygrophilus.* Reduced. (After Kerner.)
FIGURE 72. Leaf of Ratan, *Desmoncus polyacanthus.* Reduced. (After Kerner.)
FIGURE 73. Bramble, *Rubus squarrosus.* Reduced. (After Kerner.)

The suppression of normal plant organs into special structures, as tendrils and claspers, is extremely common, and, as already shown, this process if carried far enough without complete suppression will favor the production of a spiniform growth representing the axial elements of the organs. The classes of organs thus affected are practically the same as those in desert plants, though varying somewhat in manner and degree. The consolidated type of plant body is naturally absent, for, in this respect, the diffuseness of climbing plants is quite antithetical. It does not seem necessary to give a long list of examples among the climbers, illustrating the suppression of organs into spines. Although apparently not of rare occurrence, spines produced in this way are not as common as among desert plants. Two figures of the pinnate leaves of Ratan are introduced here to show the suppression of a number of the

terminal leaflets into spines (figures 71, 72). In *Machærium* the stipules are converted into thorns.[62] A tropical *Bigonia* (*B. argyro-violacea*) has normal full-sized simple leaves, and suppressed leaves bearing two opposite leaflets on one stalk, and ending "in a structure which divides into three limbs, with pointed hooked claws, and which is not unlike the foot of a bird of prey."[25]

By far the greater number of spines on climbing plants are of the nature of prickles, and are not produced by the suppression of any particular organ or organs, but appear usually without any very definite order. They represent outgrowths of the superficial layers, and hypertrophied plant hairs, or trichomes. The cause of these cortical eruptions is not clear, although they seem to be intimately connected with the general suppression of the plant body. They are therefore a secondary and not a direct result of suppression. Bailey[2] asserts that, "probably the greater number of spinous processes will be found to be the *residua* following the contraction of the plant body." This connection is very apparent in the consideration of the suppression or contraction of various plant organs, but is less obvious when applied to the surface of the whole plant, though doubtless it is the true explanation. In continuation of this idea, it may be suggested that the prickles represent aborted attempts on the part of the plant, through hereditary influences, to recover its former normal proportions. Or, they may exhibit the action of the law of repetition acting in an organism where the initial cause of spine production is the intrinsic suppression of such structures as leaves, petioles, stipules, etc. The subsequent repetition of spines on other parts of the organism results in a series of homoplastic spines which are not homologous with those first formed.

The prickles on climbing plants and brambles may often serve for purposes of protection (D_2), and enable the plant to cling to a support, but these utilitarian properties cannot be considered as an initial cause. Natural selection, also, probably has fostered the development of certain types of spiny climbers and the production of adaptive characters. Nevertheless, in studying these forms, it is necessary to revert to the original consideration of the localized suppression of normal plant structures, and to the general suppression of the plant body as affording a more primary conception of the causes and modes of spine growth among climbing plants.

In many cases of retrogressive series of animals, there seems to be a close parallelism with some of the characters observed among the climbing plants. If the Ammonite family during the Cretaceous, or near the close of the Mesozoic, is taken as an example, it cannot be said that the environment of these old

age or pathologic series is unfavorable in respect to food temperature, etc., for with them are associated many vigorous progressive series of other organisms. Neither can it be said, that in many cases the animals perished on account of over-specialization, though this was evidently the cause of the extinction of a large number. The return to a condition of second childhood in old age cannot be called a progressive specialization, since it clearly points to a deficiency of growth force.

Old age types, or phylogerontic forms, among animals may show the same attenuation or suppression of the body as do climbing plants. Thus, *Baculites*, considered by Hyatt as a typical phylogerontic type, has a very attenuate shell, and some species, after attaining a certain diameter, cease to increase in any direction except length. On account of being a chambered shell, it is manifest that the growth of the animal must have practically ceased, while its secretive activities were continued and confined largely to lengthening the shell. Other related genera of Cephalopods show a similar attenuation of the shell, evincing a stoppage of growth in the animal. Among the Mollusca, it seems quite likely that attenuation of form often accompanies decreased growth power.

The pathologic varieties of the Steinheim *Planorbis*, as described by Hyatt,[56] or of the recent *Planorbis complanatus* described by Piré,[57] are further illustrations of this attenuation accompanying the uncoiling of the shell. The sedentary *Magilus*, immersed in its coral host, is also an example, for not only does the shell cease to increase in diameter, but the whole interior, except a small cavity at the end, is filled with a solid deposit of lime. Similar examples could be multiplied indefinitely. Since, however, but few of them are spiniferous, their consideration does not properly come within the scope of the present discussion, though, as is well known, some of the attenuate forms often enlarge and contract periodically, such enlargements frequently leaving prominent laminæ or nodes that are sometimes differentiated into spines. They suggest the observations on growth, senescence, and rejuvenation, made by Minot,[48] who showed that in guinea pigs from a very early age, the increments of growth are in a steadily decreasing ratio to the increase of weight of the animal. This led to the general conclusion, that the whole life of an individual is a process of senescence or growing old.

Spines arising by a real pathologic or diseased condition of the individual can have little or no effect in producing a normal spiniferous variety or species. However, some note should be taken of them, especially as they may be congenital, and thus appear through several generations. In the human species, the

peculiar skin-disease known as ichthyosis sometimes produces spiniform excrescences, and the victims are commonly called "porcupine-men." The most celebrated instance was the Lambert family. Haeckel[27] gives the following account of this family: "Edward Lambert, born in 1707, was remarkable for a most unusual and monstrous formation of the skin. His whole body was covered with a horny substance, about an inch thick, which rose in the form of numerous thorn-shaped and scale-like processes, more than an inch long. This monstrous formation of the outer skin, or epidermis, was transmitted by Lambert to his sons and grandsons, but not to his granddaughters. The transmission in this instance remained in the male line, as is often the case." Other similar examples are cited by Gould and Pyle,[21] and the disease is described as "a morbid development of the papillæ and thickening of the epidermic lamellæ."

Categories of Interpretation.

Having thus far examined the factors governing the origin of spines, and found that they could be grouped into a number of distinct categories, it is now desirable to interpret these results, and endeavor to arrive at the real significance of the spinose condition.

The two main generalizations which will be discussed are, first, that spinosity represents the limit of morphological variation, and second, it indicates the decline or paracme of vitality.

Spinosity a Limit to Variation.

A number of data have already been given, leading to the belief that, on becoming spinose, organisms have reached a limit of morphological variation. They may continue to develop more and more differentiated and compound spines, but no new types evolve out of such a stock.

The subject may be treated in two ways, both leading to the same conclusion. First, the stages and processes involved in the growth of a spine itself may be studied, and next the development of spines in the ontogenies and phylogenies of animals and plants may be examined.

The growth of a spine has already been described, and it was shown that this type of growth may arise from specialization of other ornamental features, such as nodes, ridges, and lamellæ, and also from the decadence of leaves, legs, etc. These observations and numberless others which could be made will be sufficient to show that almost any kind of superficial structure, as knobs, tubercles, ridges, laminæ, reticulations, etc., has by differential growth been changed into spines; also, that organs

of various kinds, as legs, branches, leaves, etc., have by atrophy been reduced to spines. In each case, the parts in their development pass through the various intermediate stages, and clearly show that the spine is a result and not a mean. Moreover, none of these structures or organs is developed through the contrary process; namely, that of beginning with spines and passing through stages corresponding to laminæ, ridges, tubercles, etc. The spine is the limit, and out of it no further structure is formed.

It is necessary to make some mention here of the movable spines of Echinoderms, which appear to form an exception to the foregoing statements. There seems to be no doubt that the fixed and movable spines, the pedicillariæ, the paxillæ, and the spheridia are homologous structures, and that all begin as spiniform skeletal outgrowths, which by subsequent growth and modification produce the structures mentioned (Agassiz[1]). The echinoderm skeleton, including spines, etc., is deposited in the midst of living tissue, and in the case of the spines cannot be directly correlated with the spines of other classes of organisms, which are either very deficient in vitality or are dead structures as soon as completed. After the movable spines of echinoderms are fully developed, the living portion is often confined to the base, and the shaft becomes simply a dead structure upon which encrusting organisms may find lodgement, a condition seldom occurring in the living spines. These finished spines never develop into anything else, and are the structures which conform to the present discussion. The embryonic condition of the spines and pedicillariæ shows that they are really more internal than external structures, and therefore remain under the full control of the ordinary processes of growth, resorption, and modification by living tissues. Furthermore, the movable spines are of such functional importance that no close homologies can be made with ordinary spines found in other classes of organisms.

In tracing the ontogeny of a spinose form, it has been found (pp. 14–17) that each species at the beginning was plain and simple, and at some later period, spines were gradually developed according to a definite sequence of stages. Usually after the maturity of the organism, the spines reach their greatest perfection, and in old age, there is first an over-production or extravagant differentiation followed by a decline of spinous growth, and ending in extreme senility with their total absence.

There are abundant reasons for believing that the radicles of groups are undifferentiated and inornate, and whenever a class has had a long existence, it has been by the continuance of such radical types or by the development of secondary or tertiary

radicles, which, though differing in internal characters, still retain a primitive simplicity in superficial features. The early stages of ontogeny of any form should agree with the radical stock, and, as already noted, these stages are simple. Hyatt[34] says on this point: "the evidence is very strong that there is a limit to the progressive complications which may take place in any type, beyond which it can only proceed by reversing the process, and retrograding. At the same time, however, the evidence is equally strong that there are such things as types which remain comparatively simple, or do not progress to the same degree as others of their own group. Among Nautiloidea and Ammonoidea these are the radicle or generator types. No case has yet been found of a highly complicated, specialized type, with a long line of descendants traceable to it as the radicle, except the progressive; and all our examples of radicles are taken from lower, simpler forms; and these radicle types are longer-lived, more persistent and less changeable in time than their descendants."

A few examples will now be taken from the life histories of large groups. In the Brachiopods, the order Protremata, containing most of the spinose forms, has 4 genera and 22 species in the Cambrian of America, 20 genera and 173 species in the Ordovician, and 30 genera in the Silurian. "Then began a steady decline, with extinction in the Carboniferous of North America. In the Triassic of Europe this order is sparingly represented by small species, and is there essentially restricted to the family Thecidiidæ, which continues to have living representatives in the Mediterranean Sea" (Schuchert[64]). The superfamily Strophomenacea of this order is the longest lived and excelled in amount of specific differentiation, there being 608 species in North America alone (Schuchert). In this superfamily the early families and genera were without spines, it being only when *Chonetes* is reached that the first spines are found in the order. In this genus, they are along the hinge, and seem to make up for the weak and obsolescent pedicle. Greater spine growth occurs in the genera *Productella* and *Productus*, where, in extreme cases, the surfaces of both valves are thickly studded. During the Carboniferous, the spiny Productii attained their maximum both in number, length of spines, and in individual size, for here occur the largest species of all Brachiopods. This was the climax. The Permian genera are chiefly degenerate forms (*Aulosteges*, *Strophalosia*), and with the close of the Paleozoic, the family Productidæ became extinct. The order Protremata, to which this family belongs, likewise underwent a rapid decline, and

only two simple types continued on into the Mesozoic, while but one declining representative is living at the present time.

Among the Ammonites, the chief spiny forms are those occurring just before the final extinction of the group and representing the beginning of the decline of the order (*Crioceras*, *Toxoceras*, *Ancyloceras*, *Hamites*, etc.). In the Dinosaurian Reptiles, the great horned forms, *Triceratops*, *Torosaurus*,[19] etc., mark the extinction of the entire order. The great horned mammals of the Eocene, the Dinocerata, have left no descendants, and the giant Brontotheridæ, after undergoing various horn modifications through the Miocene, continued no further.

It is not desirable, however, to convey the impression that the spines or horns are alone responsible for this wholesale extinction. It has been shown that they are undoubtedly often an expression of extreme specialization, and generally they represent the limits to which superficial structures may be differentiated. Although there may be other expressions for similar conditions, yet the presence of spines is one, if not the most evident, marker of the attainment of these limits. The presence of a spine on an organ or part indicates the limit of progression or regression of that part or organ. If the spinose condition is general, or if it dominates important functions, it then indicates the limit of progression and regression of the organism.

Spinosity the Paracme of Vitality.

The physiological interpretation of spinosity is a correlative of the morphological aspect of the same condition, and, as it was found that spinosity was a limit to morphological progress or regress, it will now be shown that it also indicates the paracme or decline of physiological progress. Both inferences are drawn from the individual or ontogenetic standpoint, as well as from the racial or phylogenetic.

In the spinose individual, the decline of vitality has been studied by Geddes[20] in thorny plants. He concludes that they show a "gradual death from point backwards (i. e. *ebbing vitality*)." The requisite evidence is afforded in the experience of gardeners who generally consider spiny plants as "always given to die back," or as otherwise expressed, they "often prune themselves." It is difficult to adduce the same kind of evidence among animals, though there may be some degree of semblance between this self-pruning of spiniferous plants and the growth, death, and shedding of the antlers of the modern Deer. Stronger evidence of the relations of spinosity to the organism is afforded in the consideration of spines as

consisting wholly of the mechanical tissues. They are more or less dead structures and are usually without special physiological function. Hence, in so far as the whole or a part of an organism is spinose, it represents the ratio between the mechanical and active tissues, or between the inert and living structures.

Morris[49] correlates the mechanical and motor defenses of animals and plants in a matter bearing upon this subject as follows: "If we examine the whole range of the animal kingdom, we find every phase of combination of mechanical and motor defense, the motion growing more sluggish as the defensive armor grows more efficient. But in the whole kingdom, motion persists as one of the defensive agencies. No animal exists without some power of motion, by whose aid it withdraws or otherwise escapes from danger." He also notes that the plant kingdom, with the exception of the minute, swimming forms, possesses no defensive motion, and that mechanical defense alone exists. Under mechanical defense are included thorns, spines, etc., together with chemical appliances, as in plants with poisonous or disagreeable juices. These facts lead to the conclusion that, in proportion as animals are spinose or armored, they exhibit a vegetative type of structure, and have retrograded.

It has been shown elsewhere in this article, that the greatest development of spinose organisms occurs just after the culmination of a group, and, as this period clearly represents the beginning of the decline of the vitality of the group, the spines are to be taken as the visible evidence of this decadence. A similar observation has been made by Packard,[44] who after passing in review the geological development of the Trilobites, Brachiopods, and Ammonites, states that "these types, as is well known, had their period of rise, culmination, and decline, or extinction, and the more spiny, highly ornamented, abnormal, bizarre forms appeared at or about the time when the vitality of the type was apparently declining."

Furthermore, it is now commonly agreed that all groups have been most plastic near their point of origin, or, in other words, that during their early history, all the important or major types of structure have been developed. Their subsequent history reveals the amount of minor differentiation and specialization they have undergone. Apparently, most of the early impulses of growth, whether from the environment or from vital forces, resulted in physiological changes producing fundamental variations in function and structure. The later influences of environment and growth force are expressed in peripheral differentiation, and show that the racial or earlier characters had become fixed, and that the later or specific

features were the chief variables. The stimuli which, during the early life history of a group, were expended in internal or physiological adjustments, later produce external differentiation, and in this differentiation, spinosity is the limit. The presence of spines, therefore, indicates the fixity of the primary physiological characters, together with the consequent inability of the organism to change due to its decreasing vitality.

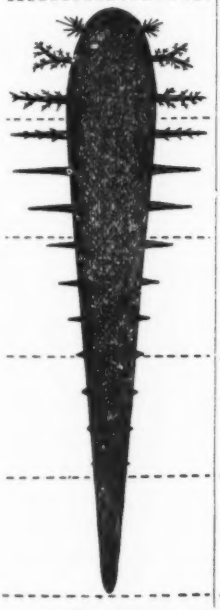
Conclusion.

Just as all our features of terrestrial topography are included between the limits of plains and mountains, and the mountains are considered as the limit of progressive accidentation, so the spines of animals or the monticules and pinnacles of their surface may be considered as the limits of progressive differentiation. The primitive base level, or peneplain, becomes elevated, and by erosion is cut up into table lands, mèsas, and buttes, with intersecting valleys. The valleys are gradually deepened, and the country becomes rougher until a maximum is reached. Then follows a reduction of the inequalities of the surface, and finally in old age, the smooth, gently rounded outlines of geographic infancy again appear. So in organisms, the smooth rounded embryo or larval form progressively acquires more and more pronounced and highly differentiated characters through youth and maturity. In old age, it blossoms out with a galaxy of spines, and with further decadence produces extravagant vagaries of spines, but in extreme senility comes the second childhood, with its simple growth and the last feeble infantile exhibit of vital power.

The history of a group of animals is the same. The first species are small and unornamented. They increase in size, complexity, and diversity, until the culmination, when most of the spinose forms begin to appear. During the decline, extravagant types are apt to develop, and if the end is not then reached, the group is continued in the small and unspecialized species, which did not partake of the general tendency to spinous growth.

Lastly, it must be determined whether spines are really hereditable characters, and therefore can be used in studying the phylogenies of groups. No one has yet been able to show any type or set of characters which cannot be transmitted from parent to offspring. Hyatt[34] says: "Everything is inherited or inheritable, so far as can be judged by the behavior of characteristics." Furthermore, in a review of animal life, extinct and living, no one can fail to be impressed with the fact that, especially near the close of the life history of a group, or in a series of highly specialized forms, spinose characters are often considered as of supra-varietal value, and are rated of specific,

generic, and sometimes of family rank, or even higher. They have therefore acquired a fixed importance in these special groups, and are recognized in the same categories with physiological and structural characters. The differences which appear at an early period in higher genera are the bases of distinction among lower genera. If the spines or other similar features do not make their appearance in an individual until a late adolescent stage, they are usually of negative value in a scheme of classification. This agrees with the general principle recently suggested by Harris,[22] that when the main features of the ornament (= spines, etc.) are foreshadowed in the larval and early adolescent stages, they are to be regarded as of taxonomic value.



Ontogeny stages.	Ontogeny condition.	Phylogeny stages.	Phylogeny condition.	Chronology.
Old age or gerontic	Paraplasis	Phylogerontic	Paracme	5
Adult or ephebic	Metaplasis	Phylephebic	Acme	4
Immature or neanic	Anaplasis	Phyloneanic	Epacme	3
Larval or nepionic	Anaplasis	Phylonepionic	Epacme	2
Embryonic	Anaplasis	Phylembryonic	Epacme	1

Diagram and table showing correlation of stages and conditions of development in the spinose individual, in its ancestry, and in time.

The preceding diagram illustrates the previous statements, and shows the correlation between the stages and conditions of growth in the ontogeny of a spinose individual, with its phylogeny, and also the chronology of groups containing spinose

forms. The numbers indicating chronology simply refer to successive periods of time. In particular cases, they may be long geologic ages as Cambrian, Ordovician, Silurian, Devonian, and Carboniferous, or in other instances they may represent much shorter periods.

From the study of the ontogenies of spinose forms, it has already been ascertained that they were simple and inornate during their young stages; and from the phylogenies of the same and similar forms, it was likewise learned that they were all derived from non-spinose ancestors. It has also been shown that spines represent an extreme of superficial differentiation which may become fixed in ontogeny, and the further conclusion, that spinosity represents a limit to morphological and physiological variation, has been reached. Finally, it is evident that, after attaining the limit of spine differentiation, spinose organisms leave no descendants, and also that out of spinose types no new types are developed.

Yale Museum, New Haven, Conn, June 1st, 1898.

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SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *On Neon and Metargon, companions of Argon in Atmospheric Air.*—On the 16th of June, Ramsay and Travers announced to the Royal Society the discovery of two new elements associated with argon in atmospheric air. Having about 18 liters of argon available, this was allowed to enter a small bulb immersed in liquefied air boiling under reduced pressure. The argon readily liquefied; and after 13 or 14 liters had disappeared, portions of the residual gas of about 50 or 60^{cc} (which evidently must contain the light gas suspected to be present) were collected, sparked with oxygen over soda, and the spectrum examined. It was found to be characterized by a number of bright red lines, among which one was particularly brilliant, and a bright yellow line, the green and blue lines being numerous but weak. The yellow line had a wave-length of 5849·6; so that it is not identical with that of sodium, helium or krypton, though resembling it in intensity. These wave lengths are as follows: Na (D_1) 5895·0; Na (D_2) 5889·0; He (D_3) 5875·9; Kr (D_4) 5866·5; Ne (D_5) 5849·6. Hence the authors propose the name "*neon*" (new) for the new gas. By means of a bulb of 32·35^{cc} capacity, the density of this neon was found to be 14·67. Since to bring it to its proper place in the periodic system, a density of 10 or 11 is required, the gas examined, if the density of argon be 20 and that of pure neon be 10, would contain 53·3 per cent of it.* That this gas—which appears to be the substance hinted at in Ramsay's Toronto address—is really new seems to be proved, not only by its spectrum and by its low density, but also by its behavior in a vacuum tube. Unlike helium, argon and krypton, it is rapidly absorbed by the red-hot aluminum electrodes, and as the pressure falls the appearance of the tube changes from a fiery red to a brilliant orange; a phenomenon shown by no other gas. Moreover, it is monatomic.

During the liquefaction of the argon, a considerable quantity of a white solid was observed to separate, in part round the sides of the tube and in part beneath the surface of the liquid. On distilling off the liquid argon, this white solid evaporated very slowly, so that finally it remained alone in the bulb. This bulb was then connected with mercury reservoirs and two fractions of about 70 or 80^{cc} each, consisting of the gas from the volatilized solid, were collected. In a vacuum tube, this gas showed a very complex spectrum. With low dispersion, it appeared banded; but with a grating, equidistant single bright lines appear throughout the spectrum, with fainter ones intermediate. The bright lines in the green are: first band, 5632·5, 5583·0, 5537·0; second band, 5163·0, 5126·5. In the first blue band 4733·5, 4711·5; second blue band, 4604·5; third blue band (1st order), 4314·0;

* On subsequent fractionation, the density decreased to 13·7.

fourth blue band (2d order), 4213·5; fifth blue band (1st order), about 3878. The red pair of argon lines were also faintly visible. The density of this gas, determined as before, was 19·87, not differing sensibly from that of argon. On determining the ratio of specific heats for this new gas, it was found to be 1·660; thus showing that it is monatomic like neon. From the fact that, both in its spectrum, and in its behavior at low temperatures, this gas differs very markedly from argon, the authors regard it as a distinct elementary substance and propose for it the name "*metargon*"; suggesting that it stands to argon as nickel does to cobalt, having approximately the same atomic mass but different properties. The reason that krypton does not appear in the higher fraction of argon, the authors explain by the fact first, that to prepare it, the manipulation of no less than 60000 times the volume of the impure sample they obtained, was required; and second, that while metargon is a solid at the temperature of boiling air, krypton is probably a liquid and so more volatile. Moreover the liquid air from which the krypton had been obtained had been previously filtered.—*Chem. News*, lxxviii, 1, July, 1898; *C. R.*, cxxvi, 1762, June, 1898. G. F. B.

2. *On Metargon.*—It has been pointed out by DEWAR that on liquefying a sample of argon obtained from Lord Rayleigh, about 250^{cc} in volume, contained in a bulb with a quill tube attachment, by immersion in liquid air, it always yields a perfectly clear liquid free from turbidity or opalescence. Since very small fractions of a per cent of impurity in a gaseous substance, separating as a solid, can be readily detected in this way, for example the 0·04 per cent of carbon dioxide in dry air or 0·1 per cent of chlorine in oxygen, it is remarkable that one per cent of a gas giving a white solid at the temperature of liquid air, could escape detection if it existed in the sample of argon furnished by Lord Rayleigh.—*Chem. News*, lxxviii, 70, August, 1898. G. F. B.

3. *On the Density and Boiling Point of liquid Hydrogen.*—At the meeting of the Chemical Society on June 2d, DEWAR gave further facts concerning liquid hydrogen. Its boiling point in air determined by a platinum resistance thermometer was found to be 35° absolute or −238° C.; a value higher by about 17 per cent than the value which Olszewski obtained by adiabatic expansion. Since its critical point must be about 50° absolute, the whole range of liquid hydrogen is only about 50° absolute. Hence there can be only a few degrees + or − difference in the estimates of the boiling point deduced from theory; though in fact this is a large percentage of the whole, the range being so small. Hence we may predict almost certainly that with no conceivable means at our present command, shall we ever be able to get nearer the absolute zero than −250° C., or say +20° absolute. In other words, the practical fall in temperature given by liquid hydrogen under high exhaustion will never exceed 10° or 15° below the present boiling point. As to its density, since it appears as a transparent liquid, having a well-defined meniscus,

and dropping readily from one vessel to another, a density not unlike that of marsh gas would be suggested; this being 0·41 at its boiling point in air. By allowing 10^{cc} of liquid hydrogen to evaporate, collecting the gas and measuring its volume, the approximate density, however, was found to be rather less than 0·07. The liquid therefore is about one-fourteenth the density of water; *i. e.*, it bears to water the same relation that gaseous hydrogen does to air. Hence the atomic volume of liquid hydrogen is about 14, that of liquid oxygen being about 13·7; the atomic volumes at their respective boiling points being very near each other. The density of hydrogen vapor at its boiling point is about one-half that of air; approaching that of marsh gas. The ratio of hydrogen vapor to the liquid is as 1 : 100, whereas this ratio in the case of oxygen is 1 : 255. "Liquid hydrogen is in all respects the most extraordinary fluid chemists have ever had to deal with. No chemist could have anticipated that a liquid with a density of one-fourteenth that of water could have been capable of collection and manipulation in vacuum vessels with the same ease practically as manipulation with liquid air was carried on ten years ago and that by its means we shall approach within 20° or 25° of the absolute zero."—*Chem. News*, lxxvii, 261, June, 1898. G. F. B.

4. *On the Boiling Point of Liquid Ozone.*—Ozone was obtained as a liquid, indigo-blue in color, by Hautefeuille and Chappuis in 1882. In 1887 Oslzewski roughly fixed its boiling point at −106°. TROOST has now repeated the experiment and has determined the boiling point with greater accuracy. The ozone was obtained by means of a Berthelot ozonizer, kept at −79° by a mixture of solid carbon dioxide and methyl chloride. The liquefaction was effected in a vertical tube, the lower portion of which was immersed in a bath of liquid oxygen contained in a Dewar double bulb. The ozone liquefies before reaching the part of the tube thus immersed, and collects in small drops having an oily appearance and not wetting the glass. An iron-constantin couple was employed to fix the temperature, used in connection with a Deprez-d'Arsonval galvanometer. A curve was obtained for the apparatus using the temperatures of melting ice, of boiling methyl chloride, of mixtures of solid carbon dioxide and methyl chloride (controlled by the hydrogen thermometer), of boiling nitrous oxide, of liquid ethylene, of melting solid ethylene and of the boiling point of oxygen. In this way the temperature could be read to within half a degree. One of the junctions of the thermo-couple was placed in the liquid ozone, the other was placed in melting ice. The bath of liquid oxygen was thus lowered until its free surface was about 3^{cm} below the lower end of the tube containing the ozone, and the galvanometer deflections were noted. At first they decreased, but finally became steady, remaining so during the time that the ozone was in ebullition, when they fell again rapidly. Transferred to the curve, the stationary point corresponds to a temperature of −119°.

Repetition of the experiment gave uniformly the same result. The boiling point of liquid ozone at the atmospheric pressure may therefore be taken as −119°. The liquid oxygen required in these experiments was obtained by the use of a Dewar apparatus utilizing commercial compressed oxygen expanded after having traversed a long serpentine tube cooled to −79°. In this way, in less than half an hour, a quarter of a liter of liquid oxygen can be obtained in the laboratory or lecture room, without the use of compression pumps or motive power.—*C. R.*, cxxvi, 1751, June, 1898; *Chem. News*, lxxviii, 29, July, 1898. G. F. B.

II. Miscellaneous Scientific Intelligence.

1. *American Association for the Advancement of Science.*—The fiftieth anniversary meeting of the American Association was held at Boston from the 20th to the 27th of August. The President of the meeting was Prof. F. W. Putnam of Cambridge, who has long been identified with the Association, having performed the arduous duties of Permanent Secretary for some twenty-five years. The retiring President, Dr. Wolcott Gibbs of Newport, delivered an address upon the subject "On Some Points in Theoretical Chemistry"; this is printed in full in the issue of *Science* for August 26. Addresses were also given by the Vice-Presidents of the various Sections.

The meeting was one of the largest in the history of the Association, the total registration being 903, a number surpassed only three times, once at Boston and on two other occasions when the meetings were held in conjunction with the British Association. The list of papers given below shows also a large number of entries. The place of meeting offered many attractions, both scientific and social, and the members of the local Committee did everything in their power to make the occasion successful. The numerous excursions were largely attended and highly appreciated.

The place selected for the next meeting of the Association is Columbus, Ohio, and Pres. Edward Orton, of the Ohio State University, has been elected President. The Vice-Presidents of the several sections are as follows: Section A, Alexander MacFarlane; Section B, Elihu Thomson; Section C, F. P. Venable; Section D, Storm Bull; Section E, J. F. Whiteaves; Section F, Simon H. Gage; Section G, Charles R. Barnes; Section H, Thomas Wilson; Section I, Marcus Benjamin.

The following is a list of papers accepted for reading:

Section A. *Mathematics and Astronomy.*

Mary Proctor: Making Astronomy popular.

Henry M. Parkhurst: Correction of local error in stellar photometry.

H. S. Davis: The parallaxes of 61^1 and 61^2 Cygni from a reduction of the Rutherfurd measures.

Frank Schlesinger: The Praesepe Group: measurement and reduction of the Rutherfurd photographs.

J. R. Eastman: Discordances between the north polar distances of stars derived from direct and reflected observations. The treatment of results from reflection observations at the Greenwich Observatory.

A. E. DOUGLASS: Summary of planetary work at the Lowell Observatory.

LEWIS SWIFT: Astronomy in Southern California.

F. W. COAR: Description of instantaneous azimuth and altitude charts of the heavens.

W. MAXWELL REED: Instruction in Elementary Astronomy by means of observations made by the student.

TRUMAN H. SAFFORD: Personal equations during the past century.

ARTEMUS MARTIN: Rational right-angled triangles.

J. WOODBRIDGE DAVIS: Behavior of the atmospheres of gas- and vapor-generating globes in celestial space.

ELLEN HAYES: Graphical Logic.

FRANK H. LOUD: Illustrations of the comitant method of constructing the imaginary loci of Analytical Geometry, so as to render their properties evident to the eye.

R. S. WOODWARD: The mass and moments of inertia of the earth's atmosphere. Two new forms of apparatus for measuring the acceleration of gravity. The gravitation constant and the mean density of the earth.

G. A. MILLER: The operation groups of Order 48 and those of Order $2p^3$, p being any prime number.

G. W. HOUGH: The condition of the surface of the Planet Jupiter.

GEO. E. HALE: The Yerkes Observatory and its work.

EDGAR ODELL LOVETT: General theory of anharmonics.

E. D. PRESTON: Fifty years of American Geodesy.

WILLIAM EIMBECK: The duplex base apparatus of the U. S. Coast and Geodetic Survey. Diminution of the refraction of the atmosphere with height and its effect upon trigonometrically determined elevations from reciprocal zenith distances.

ALEXANDER MACFARLANE: On the aims of the International Society for the Promotion of Quaternions and allied branches.

S. EDWARD WARREN: Some notes on "direction."

FRANKLIN A. BECHER: A short method for deriving Riemann's Theta formula.

L. E. DICKSON: A ternary and a quaternary linear congruence group simply isomorphic to the linear fractional congruence group.

A. S. HATHAWAY: Linear transformations in four dimensions.

JOHN S. HAYFORD: The limitations of the present solution of the tidal problem.

J. K. REES, HAROLD JACOBY, and Dr. H. S. DAVIS: Variation of latitude at New York City and the constant of aberration from observations with a zenith telescope at Columbia University Observatory, 1892–1898.

GEORGE A. HILL: Description of the altazimuth instrument recently constructed for the U. S. Naval Observatory.

DAVID P. TODD: New application of the prismatic camera to total eclipse.

ROLLIN A. HARRIS: On harmonic functions. A proposed tidal analyzer. A tidal abacus. The harmonic analysis of high and low waters.

ERNEST W. BROWN: Report on the recent progress in the dynamics of solids and fluids.

HENRY S. WHITE: Report on theory of invariants: the chief contributions of a decade.

ARTHUR G. WEBSTER: Report on the recent progress in the mathematical theory of electricity and magnetism.

G. A. MILLER: Report on the modern group theory.

SECTION B. *Physics.*

E. H. HALL: The measurement of thermal conductivity in iron.

L. A. BAUER: On energy and entropy. Second report on the magnetic survey of Maryland.

ERNEST MERRITT: On the magnetic deflection of diffusely reflected cathode rays. The resistance of iron wires for alternating currents of ordinary frequencies.

ERNEST MERRITT and O. M. STEWART: On the electrical properties of the vapor from the arc.

E. L. NICHOLS: The heat of fusion of ice determined in electrical units.

A. M. THIESSEN: The hysteresis of iron and steel at ordinary temperatures and at the temperature of solid carbon dioxide.

G. W. GRESSMAN: The electrical resistance of lead amalgams at low temperatures.

F. BEDELL, R. M. KLEIN and T. P. THOMPSON: The most efficient thickness of transformer plate.

N. H. BROWN: Photographic studies of the electric arc.

CARL BARUS: Exhibition of certain models in physics and dynamics.

F. H. BIGELOW: Temperature and vapor gradients in the atmosphere.

E. W. MORLEY, H. T. EDDY and D. C. MILLER: Report on the velocity of light in a magnetic field.

D. C. MILLER: A study of standard meter scales ruled on nickel, silver and glass. Exhibit of an automatic mercurial air pump designed by Prof. E. W. Morley.

S. T. MORELAND: An apparatus for determining coefficients of induction.

J. O. THOMPSON: Study of elastic fatigue by the time-variation of the logarithmic decrement.

G. W. PATTERSON and KARL E. GUTHE: A redetermination of the ampere.

KARL E. GUTHE: Polarization and internal resistance of the voltaic cell.

CHARLES F. BRUSH: A new gas.

HENRY S. WEBB: Hysteresis loss in iron for very small ranges of induction.

W. S. FRANKLIN: Note on the testing of optical glass. A lecture room experiment in electrostatics.

BARRY MCNUTT: A study of galvanic polarization.

S. S. CLARK: On a normal curve of magnetization of iron.

THOMAS GRAY: Some determinations of dielectric strength.

H. T. EDDY: Graphical treatment of mutually inductive circuits with special reference to the case of variable frequency.

E. RHOADS: The effect of fibrous structure in iron on its change of length when magnetized.

A. LAWRENCE ROTCH: Progress in the exploration of the air with kites at the Blue Hill Observatory.

C. L. NORTON: The use of window glass having a diffusive action on light.

F. P. WHITMAN: The relative brightness of pigments by oblique vision.

F. C. CALDWELL: Notes on the effect of silicon on the magnetic permeability of iron.

H. M. GOODWIN and G. K. BURGESS: The osmotic pressure of certain ether solutions and the validity of the Boyle-Van't Hoff law.

H. M. GOODWIN and M. DE KAY THOMPSON: The dielectric constant and electrical conductivity of liquid ammonia.

A. G. WEBSTER and B. F. SHARPE: A new instrument for the measurement of the intensity of sound.

A. G. WEBSTER: A new chronograph and a means of rating tuning forks. A geometrical method for investigating diffraction by a circular aperture.

A. D. COLE: The measurement of electrical oscillations of short period and their absorption by water.

J. H. SMITH: The effect of the secondary on the period of oscillation in a primary condenser circuit.

LEVI ORSER: A harmonic piano and organ.

E. B. ROSA and A. W. SMITH: The efficiency of condensers. A calorimetric determination of the energy dissipated in condensers.

J. O. REED: An acoustical micrometer.

KNÛT ÅNGSTRÖM: An instrument for measuring radiance.

C. P. MATTHEWS: A device for recording photometer readings.

W. A. ANTHONY: Polarization in the Zn-H_2SO_4 cell.

SECTION C. *Chemistry.*

H.. W. WILEY: The influence of temperature upon the specific rotary power of sucrose.

W. A. NOYES and N. M. AUSTIN: The determination of water and coke in coal.

W. F. HILLEBRAND: Notes on determination of water in coal.

CHARLES E. MUNROE: Analysis of mixed acids.

S. P. MULLIKEN and HARWOOD SCUDDER: A simple color reaction for the detection of methyl alcohol.

S. P. MULLIKEN and E. R. BARKER: Detection of the nitro group in organic compounds.

E. D. CAMPBELL and E. C. CHAMPION: Electrolytic determination of tin in tin ores.

HERMAN POOLE: The determination of undigested fat and casein in infant feces.

A. C. LANGMUIR: New method for the determination of zinc. Note on determination of arsenic in glycerine.

H. W. WILEY and F. P. VEITCH: The estimation of iron and aluminum in natural phosphates.

H. L. WELLS: Double salts.

F. W. CLARKE: The alkaline reaction of certain natural silicates.

ELLEN H. RICHARDS and WILLIS R. WHITNEY: The action of soft waters on metals.

C. LORING JACKSON and J. H. DERBY: Ferrous iodide.

CHAS. L. REESE: The action of chromic acid on hydrogen.

J. H. KASTLE: On the occurrence of strontium and barium. The oxidation of formic aldehyde by hydrogen peroxide.

J. L. HOWE and E. A. O'NEAL: Use of electric current in forming alums.

J. L. HOWE and S. G. HAMNER: The color of sulphur in the gaseous state.

CABELL WHITEHEAD: A study of the tellurides.

W. L. DUDLEY: Magnetic ferric oxide.

C. WELLINGTON: The action of various bases on metallic arsenites.

C. F. MABERY and W. O. QUAYLE: The sulphur compounds and unsaturated compounds in Canadian petroleum.

C. F. MABERY: The composition of commercial paraffine and the higher constituents of Pennsylvania petroleum.

C. F. MABERY and E. J. HUDSON: The constituents of California petroleum.

C. F. MABERY and H. L. SCHROM: Some experiments on the addition of hydrogen to acetylene.

C. LORING JACKSON: Certain peculiar reactions of the tribromnitrobenzols.

PETER FIREMAN and E. G. PORTNER: The propyl phosphines.

PETER FIREMAN and ERNESTINE FIREMAN: The action of ethers on phosphonium iodide.

W. A. NOYES: Camphoric acid: synthesis of the neighboring xylic acid.

M. GOMBERG: On tetraphenylmethane. A periodide of bromtriphenylmethane.

M. GOMBERG and A. C. CAMPBELL: Hydrazo- and azo-derivatives of tetraphenylmethane.

SAMUEL P. MULLIKEN and W. KELLEY: Oxyinduline—a new blue dyestuff.

FRANK K. CAMERON: The benzaldoximes.

A. B. PRESCOTT and H. M. GORDIN: Certain alkaloidal periodides and the volumetric estimation of alkaloids as higher periodides.

E. KNEUER: On true and bis-nitroso compounds.

T. W. RICHARDS: Progress in physical chemistry.

E. C. FRANKLIN and C. A. KRAUS: Some properties of liquid anhydrous ammonia.

A. A. NOYES and DAVID SCHWARTZ: The solubility of di-ionic salts of weak acids in solutions of stronger di-ionic acids.

A. A. NOYES and E. S. CHAPIN: The solubility of di-ionic acids in solutions of di-ionic salts of other acids. The solubility of tri-ionic bases in solutions of di-ionic salts of weak bases.

A. A. NOYES and L. J. SEIDENSTICKER: The solubility of iodine in dilute potassium iodide solutions.

A. A. NOYES and GEORGE T. COTTLE: The rate of reaction between silver acetate and sodium formate: a reaction of the third order.

E. D. CAMPBELL and W. E. HARTMAN: On the influence of silicon on the heat of solution of coke in cast iron.

C. GILBERT WHEELER: On the passage of bubbles through media of different densities.

ROMEYN HITCHCOCK: Photographic reproduction of color.

N. W. LORD: The valuation of coals.

W. P. MASON: Determination of turbidity in water. Efficiency of the Elmira filtering plant.

ISABELLE F. HYAMS and ELLEN H. RICHARDS: On the composition of *Oscillaria prolifica* and its relation to the quality of water supplies.

CHAS. L. PARSONS: The Le Seuer electrolytic process for the production of caustic soda and bleaching powder. Review of the electrolytic processes for the production of caustic soda and bleaching powder.

E. G. SMITH: The alum question in water purification.

C. F. MABERY and K. LANDGREBE: The effect of an electrolytic bath on the tanning of leather.

WM. MCMURTRIE: Some records of the year's progress in applied chemistry.

BRUNO TERNE: The progress in utilization of city garbage, with special reference to the new plant in Boston.

C. F. MABERY and E. B. BALTZLY: On the removal of hardness from water for boiling purposes.

S. M. BABCOCK and H. L. RUSSELL: On the properties of galactose.

O. W. SMITH and NORMAN PARKS: Composition of Ohio wines.

ROMEYN HITCHCOCK: New process for the commercial production of oxygen.

H. A. WEBER: Light: a factor in sugar production.

J. B. LINDSAY: The determination of starch in agricultural products.

E. W. HILGARD: A note on the growth of lupins on calcareous lands.

E. A. DE SCHWEINITZ: Some of the important results of the recent chemical investigations of plant and animal cells.

F. P. VENABLE: The use of the formula in teaching chemistry.

IRA REMSEN: The teaching of organic chemistry.

EDWARD HART: The teaching of industrial chemistry.

WM. L. DUDLEY: The teaching of analytical chemistry.

SECTION D. *Mechanical Science and Engineering.*

C. L. CRANDALL: The determination of the lamp-hours per day available for electric lighting from a storage battery plant driven by a 12-foot Aer-motor.

F. H. NEWELL: Instruments and methods of hydrographic measurements by the United States Geological Survey.

CHARLES D. WALCOTT: The development of the topographic work of the United States Geological Survey and its application to the solution of economic and engineering problems.

CHAS. L. NORTON: On the testing of steam pipe covers.

J. B. JOHNSON: Time test on dry long leaf yellow pine lumber in compression endwise. Some micro-photographs, showing the grains of Portland cement between diameters $0{\cdot}02^{mm}$ and $0{\cdot}14^{mm}$ as separated by the Schöne washing apparatus.

CHARLES F. WARNER: High speed influence machines.

CARL KINSLEY: Proposed methods of determining the frequency of alternating currents.

ROMEYN HITCHCOCK: The theory of half-tone press printing.

JOHN J. FLATHER: A combined absorption and transmission dynamometer.

F. C. WAGNER: On the use of a platinum resistance as a pyrometer in boiler tests. On the measurement of train resistance by dynamometer.

THOMAS GRAY: Note on a curious example of elastic eolotropy in steel. An integrating dynamometer for measuring the work done in drawing a train. A comparison of the efficiency of the rheostat and the series-parallel controller for electric cars.

STORM BULL: The efficiency of refrigerating plants.

L. G. CARPENTER: On the evaporation and seepage from reservoirs. Losses from rivers. Energy received from the sun.

WM. KENT: Some notes on definitions of mechanical unit.

SECTION E. *Geology and Geography.*

B. K. EMERSON: Outline map of the geology of Southern New England.

H. L. FAIRCHILD: Basins in glacial lake deltas.

A. C. HAMLIN: An exhibition of the rare gems and minerals of Mt. Mica.

C. H. HITCHCOCK: The Hudson River lobe of the Laurentide ice-sheet

ARTHUR HOLLICK: The age of the Amboy clay series as indicated by its flora.

T. C. HOPKINS: The origin of the limonite ores of Nittany Valley, Pennsylvania.

H. C. HOVEY: The region of the Causses in Southern France, with maps and stereopticon views.

C. H. RICHARDSON: The Washington limestone in Vermont.

WARREN UPHAM: Fluctuations of North American glaciation shown by interglacial soils and fossiliferous deposits. Time of erosion of the Upper Mississippi, Minnesota, and St. Croix Valleys.

G. FREDERICK WRIGHT: Supposed "Corduroy Road" of Late Glacial age, at Amboy, Ohio. The age of Niagara Falls as indicated by the erosion at the mouth of the gorge. A recently discovered cave of celestite crystals at Put-in-Bay, Ohio.

M. A. VEEDER: Changes in the drainage system in the vicinity of Lake Ontario during the Glacial period.

JOHN CRAWFORD: Recent severe seismic movements in Nicaragua.

J. W. SPENCER: Another episode in the history of Niagara River. Evidence of recent great elevation of New England.

BENJAMIN HOWARD: Geography and resources of the Siberian Island of Sakhalin.

G. F. MATTHEW: The oldest Palæozoic fauna.

N. H. WINCHELL: The oldest known rock. The origin of the Archean igneous rocks.

C. R. VAN HISE: Joints in rocks.

E. O. HOVEY: Notes on some European museums.

W. O. CROSBY: History of the Blue Hills complex.

AMADEUS W. GRABAU: Palæontology of the Cambrian terranes of the Boston basin.

E. M. SOUVIELLE: Diamonds in meteorites.

HARRY F. REID: The periodic variations of glaciers.

(*Papers presented by the Geological Society.*)

ARTHUR HOLLICK: Some features of the drift on Staten Island, N. Y.

N. S. SHALER: Loess deposits of Montana. Spacing of rivers with reference to the hypothesis of base-leveling.

H. L. FAIRCHILD: Glacial waters in the Finger Lake region of New York.

H. F. REID: The stratification of glaciers.

WARREN UPHAM: Evidence of epeirogenic movements causing and terminating the ice age.

G. FREDERICK WRIGHT: Clayey bands of the glacial delta of the Cuyahoga River at Cleveland, O.

H. FOSTER BAIN and A. T. LEONARD: The Middle Coal Measures of the western interior coal field.

CHARLES R. KEYES: The principal Missourian section.

H. B. PATTON: Tourmaline and tourmaline schists from Belcher Hill, Jefferson Co., Colorado.

A. C. LANE: Magmatic differentiation in the rocks of the copper-bearing series. Note on a method of stream capture.

C. R. VAN HISE: The volume relations of original and secondary minerals in rocks.

W. G. TIGHT: The development of the Ohio river.

F. P. GULLIVER: Classification of coastal forms. Dissection of the Ural Mountains. Note on Monadnock.

C. WILLARD HAYES: The Continental divide in Nicaragua.

(*Papers presented by the National Geographic Society.*)

MARCUS BAKER: The Venezuela-British-Guiana boundary dispute.

JOHN HYDE: Considerations governing recent movements of population.

GIFFORD PINCHOT: Some new lines of work in Government forestry.

W. J. MCGEE: The development of the United States.

M. S. W. JEFFERSON: Atlantic estuarine tides.

HENRY GANNETT: The forestry conditions of Washington state.

CHARLES H. FITCH: The five civilized tribes and the topographic survey of Indian territory.

R. U. GOODE: Bitter Root forest reserve.

SECTION F. *Zoology.*

ALPHEUS HYATT: Evolution and migration of Hawaiian land shells. A new classification of fossil Cephalopods.

J. B. SMITH: Notes on the habits of some burrowing bees. A new method of studying underground insects.

A. S. PACKARD: On the systematic position of the trilobites. On the Carboniferous fauna of Rhode Island. On the markings of Nodontian larvæ.

F. P. GORHAM: Some points in the Oögenesis of *Virbius zostericola* Smith. A new species of pigment producing pathogenic bacillus.

C. S. MINOT: On the types of vertebrate embryos. On the embryology of the rabbit.

H. S. WILLIAMS: Variation versus heredity.

L. O. HOWARD: The proposed attempt to introduce *Blastophaga psenes* into California.

C. L. MARLATT: The records for 1898, of Broods VII and XVII, of *Cicada septendecim.*

W. H. ASHMEAD: On the genitalia of ants, and their value in classification.

E. O. HOVEY: Naples station: general description and notes on methods of work employed there. General statement of types and figured specimens of fossil invertebrates in the American Museum of Natural History. Measurements of two large lobsters, recently added to the collections of the American Museum of Natural History.

WM. H. DALL: On the present state of our knowledge of the North American Tertiary mollusk-fauna.

C. R. EASTMAN: Some new points in Dinichthyid.

W. GRABAU: Moniloporidæ, a new family of Palæozoic corals.

JOHN MURDOCH: An Historical notice of Ross' rosy gull, *Rhodostethia rosea.*

T. JACKSON: Localized stages in growth.

THEO. GILL: On the piscine ancestors of the Amphibians.

JAS. LEWIS HOWE: Variation in the shell of *Helix nemoralis* in the Lexington, Va., Colony.

S. H. GAGE: Hibernation, transformation, and growth of the common toad (*Bufo lentiginosus americanus.*) The transformation of the brook lamprey (*Lampera wilderi*) and parasitism among lampreys.

W. L. POTEAT: Leidy's genus Ouramœba.

C. M. WEED: The winter food of the chickadee.

T. JACKSON: Ink and paper for museum labels.

W. B. ALWOOD: Notes on life history of *Protoparce carolina.* The life history of *Schizoneura lanigera.*

EDWARD S. MORSE: Remarks on Aphorphora.

HARRISON G. DYAR: The phylogeny of the North American Eucleidæ.

G. W. FIELD: On the anatomy and physiology of the spermatozoa of invertebrated animals.

C. B. DAVENPORT: Fauna of Cold Spring Harbor.

SECTION G. *Botany.*

BRADLEY M. DAVIS: The carposporic type of reproduction of Rhodophyceæ.

H. J. WEBBER: Origin and homologies of blepharoplasts. Notes on the strand flora of Florida.

W. J. BEAL: Leaves of red Astrachan apples immune from the attack of *Gymnosporangium macropus.* The work performed by the Agricultural College toward a Botanical Survey of Michigan. Some examples illustrating modes of seed dispersion. Remarkable decrease in the size of leaves of *Kalmia angustifolia*, apparently due to reduction of light.

BYRON D. HALSTED: Starch distribution as affected by fungi. Half shade and vegetation. Influence of a wet spring on parasitic fungi.

ERNST A. BESSEY: The comparative anatomy of the pistils of apocarpous families.

W. R. SHAW: The blepharoplast in the spermatogenesis of Marsilia.

C. S. CRANDALL: Observations on the relative moisture content of fruit trees in winter and in summer.

H. L. BOLLEY: Some investigations bearing upon the symbiotic mycoplasm theory of grain rust.

C. O. TOWNSEND: The effect of an atmosphere of ether upon seeds and spores.

RODNEY H. TRUE: The toxic action of a certain group of compounds.

C. L. POLLARD: Types of vegetation on the keys of South Florida.

E. F. SMITH: Potato as a culture medium, with some notes on a synthesized substitute. Some little used culture media which have proved valuable for species differentiation. Observations on Stewart's sweet-corn germ.

D. T. MCDOUGAL: Temperature and transportation of desert plants.

W. ALWOOD: The brown spot disease of apple leaves, *Phyllosticta pirina*, and fungus forms associated therewith. On the occurrence of a yeast form in the life cycle of *Sphaeropsis malorum* Peck.

H. VON SCHRENK: Notes on some diseases of Southern pines.

D. G. FAIRCHILD: The Botanic garden at Buitenzorg, Java.

CHARLES E. BESSEY: Notes on the relative infrequency of fungi upon the Trans-Missouri Plains and the adjacent foothills of the Rocky Mountains.

KATHERINE E. GOLDEN and C. G. FERRIS: Fermentation without live yeast cells.

KATHERINE E. GOLDEN: Deterrent action of salt in yeast fermentation.

O. F. COOK and D. G. FAIRCHILD: Fungus gardening as practised by the Termites in West Africa and Java.

S. M. BABCOCK and H. L. RUSSELL: The biology of cheese-ripening.

LILLIAN SNYDER: A bacteriological study of pear blight.

MERTON B. WAITE: Life-history and characteristics of the pear-blight bacillus.

G. H. HICKS: Effect of fertilizers on the germination of seeds.

B. M. DUGGAR: Development of the pollen grain in Symplocarpus and Peltandra.

E. J. DURAND: The embryology of Taxus.

K. M. WIEGAND: Notes of some monocotyledonous embryo-sacs. Studies relative to the perigynium of the genus Carex.

J. M. MACFARLANE: Observations on some hybrids between *Drosera intermedia* and *Drosera filiformis*.

E. SIMONS and R. E. B. MCKENNEY: On the rapidity of circumnutation movements in relation to temperature.

THOMAS H. KEARNEY: General characteristics of the Dune flora of Southeastern Virginia. Vegetation of the wooded fresh-water swamps of Southeastern Virginia.

CHARLES LOUIS POLLARD: On the validity of the Genera *Senna* and *Chamæcrista*. Species characters among the violets.

W. W. ROWLEE: Notes on Arctic willows.

EDWARD S. BURGESS: Some steps in the life history of asters.

T. H. MACBRIDE: The Pleistocene and plant-distribution in Iowa.

E. B. COPELAND: A self-registering transpiration machine.

L. R. JONES: Methods of studying the sap pressure of the sugar maple.

RODNEY H. TRUE: Notes on the physiology of the sporophyte of certain mosses.

W. W. ROWLEE and GEORGE T. HASTINGS: The seeds and seedlings of some Amentiferæ.

P. BEVERIDGE KENNEDY: The morphology and taxonomic value of the fruits of grasses.

L. H. PAMMEL: The caryopsis of the Graminiæ. The ecological distribution of Colorado and Wyoming plants.

F. WILLIAM RANE: Fertilization of the muskmelon flower. Notes on destroying *Comptonia asplenifolia*. Length of time from blossoming until seed development of *Leucanthemum vulgare*.

(*Papers presented by the Botanical Society.*)

M. L. FERNALD: Note on the influence of eskers upon plant distribution in Maine.

K. M. WIEGAND: Some peculiar features of synapsis in the pollen-mother cells of monocotyledons. Is the present treatment of the species of *Hydrophyllum* a natural one?

HERMAN VON SCHRENK: The future growth of *Taxodium distichum*.

JOHN F. COWELL: Progress of work on the Buffalo Botanic Garden.

B. M. DUGGAR: The nucleolus during the division of the pollen-mother cells in *Begonia*.

E. J. DURAND: An apparatus for washing. Material killed by certain fixtures.

HOLLIS WEBSTER: Notes on the occurrence near Boston of some fleshy fungi.

B. M. DUGGAR: The influence of temperature upon *Sporotrichum globuliferum*.

A. B. SEYMOUR: North American *Ustilagineæ*.

SECTION H. *Anthropology.*

D. G. BRINTON: Typological analysis. Anthropological terminology.

J. W. POWELL: Sophiology, or the science of the evolution of opinion.

W. J. McGEE: Papago medicine. Some definitions in anthropology.

W. H. HOLMES: Anthropological problems of the Pacific Slope. Museum presentation of anthropology.

ALICE C. FLETCHER: The significance of the garment, a study of the Omaha Tribe.

ALICE C. FLETCHER and W. MATTHEWS: The earth lodge.

J. C. FILLMORE: The harmonic structure of Indian songs.

FRANCIS LA FLESCHE: Ritual of the Sacred Pole of the Omahas. (Phonograph Records.)

JEANETTE R. MURPHY: The survival of African music in America.

CORNELIA HORSFORD: Some of the evidences that Northmen were in Massachusetts in pre-Columbian times.

G. A. DORSEY: Subjects relating to the physical anthropology of North American Indians.

A. L. KROEBER: The Smith Sound Eskimo.

HUGH H. LUSK: The Maori of New Zealand; his history and country.

DEAN C. WORCESTER: "Moros," or Malay pirates of the Southern Philippines. The Philippine Islands and their people.

H. C. MERCER: The tools of the American pioneer. The origin of domesticated animals.

M. H. SAVILLE: Burial customs of the ancient Zapotecans of Southern Mexico. Notes on the Lacandon Indians of Mexico.

FRANK H. CUSHING: Tomahawk and shield. Examples of primitive fire-working from Florida.

THOMAS WILSON: Art in prehistoric times. Prehistoric musical instruments. Arrow-points, spear-heads and knives.

WILLIAM WALLACE TOOKER: Problem of the Rechahecrian Indians of Virginia. The Swastica and other marks among the Eastern Algonkins, a preliminary study.

STANSBURY HAGAR: The water burial time.

R. J. FLOODY: Time-reckoning among early people. The rite of circumcision among the early races.

DANIEL FOLKMAR: Anthropology, not sociology, as an adequate philosophy.

M. A. CLANCEY: Science the basis of morals.

A. HRDLICKA: Anthropological differences between typical white and negro girls of the same age. Variations of the normal tibia.

W. Z. RIPLEY: Résumé of recent studies on the origins of European races. Presentation of a bibliography of the anthropology and ethnology of Europe.

D. A. SARGENT: Typical American students, illustrated by charts and statues.

G. W. FITZ: A new kymographion; a new chronoscope.

J. McKEEN CATTELL: Anthropometric instruments.

HUGO MÜNSTERBERG: Psychology and art.

MRS. C. LADD FRANKLIN: The new theory of the light sense.

WALTER HOUGH: Social organization and laws of the Moki Indians. Korean Clan organization.

FREDERICK STARR: The Otomies of Mexico.

FRANK BAKER: The illusions of craniometry.

MATILDA C. STEVENSON: Zuni witchcraft.

CH. H. HENNING: Origin of the Confederacy of the Five Nations.

EDWARD S. MORSE: Is the stringed muiscal instrument pre-Columbian?

PAUL DU CHAILLU: The Norsemen, the conquerors of Britain.

DESIRE CHARNAY: The disappearance of the Cliff Dwellers.

SECTION I. *Economic Science and Statistics.*

B. E. FERNOW: The College of Forestry at Cornell University.

EDWARD ATKINSON: High wages in money, or what money will buy, the consequent of low cost of production. How to increase exports and how not. The inherent vice of legal tender.

S. EDWARD WARREN: Local life by local times. A study of competition and suburban prices.

CORA A. BENNESON: Executive discretion in the United States.

Mrs. DANIEL FOLKMAR: The short duration of school attendance: causes and remedies.

E. L. CORTHELL: The progress of the maritime commerce of the world during the past fifty years.

WOLFRED NELSON: Cuba: past, present, and future.

EDWARD T. PETERS: Examination of the theory of rent.

HENRY FARQUHAR: The price of wool.

J. S. WILLISON: The transportation problem.

W. H. HALE: The formative period of a great city: a study of Greater New York.

JOHN HYDE: Deviations from the normal in the annual rate of agricultural production.

H. T. NEWCOMB: Railway rates and competition.

C. A. EATON: A sufficient social principle.

R. T. COLBURN: Why not try a North American Zollverein?

WOLFRED NELSON: Nicaragua and the canal.

C. B. SPAHR: The gold standard and the unemployed.

F. R. RUTTER: The effect of tariff legislation on the importation and domestic production of sugar in the United States.

JOHN DAVIDSON: The ethical function of the economist. The development of colonial policy.

Mrs. HELEN DAVIDSON: The economic status of the nurse.

MARCUS BENJAMIN: American Industrial Expositions, their purposes and benefits.

W. FELT: Scientific bookmaking.

W. R. LAZENBY: A plea for manual and industrial training in horticulture.

ROBERT T. HILL: The economic possibilities of Cuba.

W. LANE O'NEILL: On the United States' alleged policy of imperialism, so-called, and in connection therewith, some reasons for and against the proposed Anglo-Saxon alliance.

A. W. CAMPBELL: The economic value of good roads.

S. MORLEY WICKETT: The study of political economy in Canada.

C. C. JAMES: The agricultural statistics of Ontario.

THOMAS SOUTHWORTH: Canadian forests and the paper industry.

HENRY C. BOLTON: A catalogue of scientific and technical periodicals, 1665 to 1885.

2. *British Association.* — The sixty-eighth meeting of the British Association for the Advancement of Science was held at Bristol from September 7 to 14: this is the third time the city has been thus honored. The meeting was thoroughly successful both in scientific results and in attendance, as recorded in the issues of *Nature* for Sept. 8 and following dates. The inaugural address, delivered by the President, Sir William Crookes, was largely devoted to a discussion of the probable food supply available in the future for the increasing population of the earth. After showing "that England and all civilized countries stand in deadly peril of not having enough to eat," the speaker indicated that some comfort could be found in various directions, particularly in the probable solution of the problem of obtaining nitrates for enriching exhausted soils from atmospheric nitrogen by electrical means. The address also included an interesting account of recent progress in the departments of physics and chemistry, to which the speaker had especially devoted himself.